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A RAND NOTE

Situational Force Scoring: Accounting for Combined Arms Effects in Aggregate Combat Models

Patrick Allen

RAND

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PREFACE

This Note is an initial attempt to describe a framework for situational adjustments to ground force scores, with proposed initial values for this methodology. RAND has implemented this methodology in the RAND Strategy Assessment System (RSAS). It has begun sensitivity tests and, on a funding-limited basis, comparisons with higher-resolution models. One result of these tests is expected to be changes to the values proposed herein; experience with this approach may also cause us to adjust the methodology. Subsequent updates of this Note are thus anticipated. Indeed, readers should consider this Note as interim documentation of work in progress, documentation making it possible to expand the range of people able to review and contribute to the research.

This Note was prepared as part of the continuing development of the RSAS sponsored by the Director of Net Assessment in the Office of the Secretary of Defense. It attempts to respond in part to concerns of the Director of Net Assessment with current military modeling procedures and the state of American military science. This is the first in a series of Notes to address problems in these areas. The RSAS effort is conducted as part of RAND's National Defense Research Institute (NDRI), a federally funded research and development center sponsored by the Office of the Secretary of Defense and the Joint Staff. Comments are welcome and should be addressed to Dr. Charles Kelley, Director of the International Security and Defense Strategy Program at RAND.

In addition to this Note, an Apple Macintosh 3.5-inch disk with the Excel spreadsheets described in Appendix C of this paper is available through RAND. For a copy of this disk, please contact Dr. Bruce Bennett in the RAND Washington Office, or the author or Dr. Paul Davis in the RAND Santa Monica Office.

SUMMARY

OBJECTIVES

The situational force scoring (SFS) methodology has two objectives: (1) To improve the representation of ground force close combat in aggregate combat models that use scores of one form or another to compute force ratio, attrition, and movement as a result of combat; and (2) To provide an alternative extrapolation mechanism for use in more-detailed weapon-on-weapon models that depend on data that is available only for a modest number of calibration points.

SFS seeks to accomplish the first objective by adjusting the scores dynamically to reflect the effects of the type of terrain, type of battle, and combined arms imbalances or shortages on each side's effective force scores. The SFS methodology significantly mitigates many long-standing problems of aggregate models, such as their underestimating the relative value of light units even in situations where they are in fact highly effective, even more effective than armored units. For example, infantry in prepared defenses in urban or mountainous terrain can be very effective against armor, but this relative effectiveness is ignored in aggregate combat models, which do not account for this situation. Combat models that ignore these effects are likely to be biased against infantry and in favor of armor, given the standard base cases used for scoring and evaluating combat forces. An example of a combined arms effect with respect to force mix is the suppressive effect of artillery in support of an armor and infantry assault, especially against prepared or fortified defenses. The benefit of the attacker's artillery is not in just the targets it destroys, but in the effect its fires have on suppressing the enemy's ability to engage friendly attacking maneuver assets. Even an aggregate model should represent the limited ability of an attacker to successfully penetrate prepared defenses without sufficient artillery support. Aggregate models employing the SFS should be very useful in policy analysis, higher-level war-gaming, and screening studies attempting to make first-cut assessments of alternative force mixes over a wide variety of scenarios.

A common alternative to aggregate models are, of course, higher-resolution weapon-on-weapon combat (as opposed to force-on-force) methodologies. Examples of weapon-on-weapon methodologies include heterogeneous Lanchester equations and killer-victim (KV) scoreboard methodologies such as the attrition-calibration (ATCAL) used by the Army's Concepts Analysis Agency or the anti-potential/potential (APP) method used in the Institute for Defense Analyses' TACWAR model. However, these more detailed methodologies have

their own problems, such as significantly higher data requirements than force-on-force methodologies, a limited capability to extrapolate combat results to cases for which there are no calibration data available, and the inability to function at all in the absence of detailed data.

Based upon the preceding limitations of more-detailed methodologies, the second objective of the SFS methodology is to provide an alternative extrapolation mechanism that employs detailed weapon-on-weapon data when available, but also handles situations where more detailed information is not available. The SFS methodology can be calibrated precisely to baseline killer-victim scoreboards available from high-resolution combat models such as COSAGE (combat sample generator) or JANUS. When extrapolating to off-calibration cases, SFS produces results somewhat differently than the more detailed killer-victim scoreboard methodologies. Whether the SFS will be better or worse than other methodologies for this role is not yet clear, but we anticipate that the SFS will at least prove complementary to existing KV-scoreboard methodologies. For example, ATCAL and CADEM (a new differential equation model under development at RAND) could be used to help calibrate the SFS parameters, as shown in Section 7. Conversely, the SFS parameters could be used to help calibrate the CADEM methodology when more detailed information is not available.

THE SFS METHODOLOGY

The SFS consists of a 20-step calculation process divided into four stages that adjust force scores for a variety of factors.[1] To keep the methodology understandable, each calculation step requires simple calculations, such as addition, subtraction, multiplication and division. The four stages are:

- Varying the strength of each category of weapon as a function of the terrain and type of engagement.
- Modifying category multipliers to account for shortages in the combined arms mix.
- Calculating combat outcomes, including losses to each side and the FLOT (forward line of own troops) movement rate.
- Calculating the casualty distribution across each category of weapon.[2]

[1]There is also a less-detailed version of the SFS methodology based upon type unit. This is described in detail in Appendix A.

[2]Casualty distribution is defined here as determining detailed losses of weapon systems by type of system. For example, the fraction of tanks lost will not be the same as the fraction of artillery pieces lost or the fraction of infantry lost. Yet aggregate scoring mechanisms have traditionally distributed

The SFS methodology requires data with the appropriate magnitudes and directions for the combined arms effects being represented. The data used to calibrate SFS can be derived from high-resolution simulations (as mentioned above), historical analysis, military judgment, and analytic assumptions about continuity. The baseline data provided in this Note have been strongly influenced by historical analysis previously reflected in the RSAS ground combat model, analytic assumptions, and an initial conference convened to obtain organized military judgment. This first calibration conference was held at RAND in March 1991, and we hope to hold a second calibration conference in 1992. These initial calibrations appear to be significantly better than using static scores, but the methodology's database can be greatly improved over time.

An advantage of the SFS methodology over less-detailed force-on-force static scoring mechanisms is that it accounts for the benefits of employing the right types of forces in the right types of terrain and types of battles, as well as employing the right mix of forces. An advantage of the SFS methodology over more-detailed weapon-on-weapon methodologies is that it does not require reliable data from high-resolution models for all calibration cases in order to operate at all. However, the quality of the SFS calculations will be improved over time as high-resolution simulation experiments are used to improve its assumed parameter values.

One limitation of the SFS methodology is that when one is considering forces and tactics significantly different from those currently in existence and upon which judgments used to calibrate SFS parameters were implicitly based, it may be important to use high-resolution simulation and human gaming to understand the new circumstances. In addition, the SFS methodology is not designed for use in battalion-level or below simulations where line-of-sight calculations are being calculated. Thirdly, the current SFS does not adequately reflect some of the first-order effects of air forces on ground-force effectiveness (nor do any of the other combat models the author is familiar with). For example, although the SFS does include effects such as the ability of attack helicopters to mitigate shortages of armor or artillery capabilities, it does not reflect the consequences of local air superiority over the combat zone on ground combat effectiveness there. Correcting and integrating such synergistic effects is the first priority for SFS improvement.

There are actually a number of variants of the SFS methodology, as described in the text. One version is a simpler approach based upon "type units" rather than requiring data

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losses equally across the component weapon systems. For example, if a force loses 5 percent of its strength, then 5 percent losses are attributed to each of the strengths of tanks, artillery, and infantry. The SFS methodology proposes a way to account for variations in casualty distribution.

for scores and quantities by category of weapon. Other options involve producing what can be interpreted as KV-scoreboard outputs, distinguishing in a simple manner among forces with different generations of armor and anti-armor assets, allowing for conservation of scarce assets, and representing systems with both high lethality and high vulnerability.[3]

SFS APPLICATIONS

The SFS methodology has been applied as described herein to the CAMPAIGN-ALT model (or the alternate theater model, also known as S-Land [Allen and Wilson, 1987]), which represents combat in all land theaters in the world. RSAS users can apply this methodology with RSAS Release 4.5 or later. An earlier version of SFS was applied to CAMPAIGN-MT (or the main theater model), which represents combat in Central Europe and Korea. Although the applications in each model are similar in function, there are minor differences in the implementation. CAMPAIGN-ALT makes extensive use of the RAND-ABEL tables (described in Appendix B) for increased flexibility and understandability. The SFS methodology will be included in the RSAS integrated theater model (ITM), which brings together the best of CAMPAIGN-ALT and CAMPAIGN-MT into a single model.

As part of CAMPAIGN-ALT, the SFS methodology has been applied in selected RAND studies and was used successfully during the 1991 Global Game at the U.S. Naval War College (see Appendix D for an example). Due to the simplicity of the SFS design, there is no reason why this methodology could not be applied to other aggregate combat models.

[3]RAND colleague Richard Hillestad recently suggested that the SFS methodology could also account for a loss in the command and control system. For example, artillery effectiveness may be severely degraded by a disruption of one side's command and control (C2) capability. It is unclear how detailed weapon-on-weapon methodologies would account for a disruption in the C2 net.

ACKNOWLEDGMENTS

Many people contributed to the preparation and rewriting of this document over the last three years. Paul Davis, Bruce Bennett, and Robert Howe contributed to the formulation by helping define the issues and posing the tough questions, as well as assisting in the process of defining the various numbers in the tables. In addition, Paul Davis first suggested the "sample calculation" approach as the best way of presenting this new concept to the audience. Robert Howe performed the official review of this Note. Richard Hillestad suggested additional areas of strengths and limitations of the methodology. Bruce Pirnie performed sample runs and wrote Appendix D. Alicia Bell diligently created the first spreadsheet program of Lotus 1-2-3, which the author later translated into Microsoft Excel. Carl Jones and Barry Wilson implemented the SFS methodology into the CAMPAIGN-MT and CAMPAIGN-ALT (S-Land) models of the RSAS, respectively. Bruce Bennett developed the formulations and data for many of the SFS effects as applied to the RSAS, and worked with Barry Wilson to complete the final implementation process and tune the SFS parameters. Edie Kuhner, Linda Quicker, and Millie Zucker reformatted the draft for publication. Any problems remaining in the document are, of course, mine.

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1. INTRODUCTION AND PHILOSOPHY

BACKGROUND

In the real world of combat, different types of assets (such as infantry, armor, or artillery) perform better or worse in different types of terrain or engagements. Further, each asset type is more or less effective depending upon the mix of weapons in both sides' forces.

The situational force scoring (SFS) methodology has been developed to better account for situation-dependent combined arms effects in aggregate combat models. It can be used to improve aggregate models, or used in coordination with mid-level resolution models using killer-victim scoreboard methods, as described below. In aggregate models, the value of a force is determined from its component systems, and combat is assessed as a function of the opposing aggregate force values. Homogeneous Lanchester equations and force scoring mechanisms are two examples of force-on-force methodologies. There are several aggregate force scoring mechanisms, such as WEI/WUV (weapon effectiveness index, weighted unit value), DEF (division equivalent firepower), and TASCFORM (a technique for assessing comparative force modernization). All have been subject to much criticism, primarily due to lack of accounting for situation-dependent combined arms effects and inadequately representing casualty distribution. The SFS methodology defines a series of multipliers that can be applied to any of these existing force scoring mechanisms.[1]

Most aggregate combat models ignore many of the most basic combined arms effects in their assessment processes. For example, in most force-on-force combat assessment methodologies, an armored unit is always valued as stronger than an infantry unit whether it is fighting in open terrain, rough terrain, or urban terrain. Conversely, an infantry unit is always valued less highly than an armored unit of the same size, even if it is fighting from prepared positions in urban or mountainous terrain.

In reality, an infantry unit in mountainous terrain with prepared defenses and sufficient antitank capability will be able to stop an armored unit several times its size. In addition, only infantry can take and hold terrain. Similarly, most models do not account for the need for artillery in certain situations. For example, artillery is very important to an

[1]Casualty distribution is defined here as determining detailed losses of weapon systems by type of system. For example, the fraction of tanks lost will not be the same as the fraction of artillery pieces lost or the fraction of infantry lost. Yet aggregate scoring mechanisms have traditionally distributed losses equally across the component weapon systems. For example, if a force loses 5 percent of its strength, then 5 percent losses are attributed to each of the strengths of tanks, artillery, and infantry. The SFS methodology proposes a way to account for variations in casualty distribution.

attacker attempting to assault prepared defenses. Without the ability to mass artillery fires and suppress the defenders, the losses to attacking maneuver units will probably be higher. This tendency to assign fixed values to weapon systems (such as tanks versus infantry or artillery) independent of the combat situation leads to relative unit scores that are unrealistic in many frequently encountered combat situations.

In the approach proposed in this Note, the value of each of a unit's component weapon systems is varied as a function of the combat situation (defined by type of terrain and type of battle) and as a function of shortages in the weapon mix in a given combat situation. We have called this proposed methodology "situational force scoring."

There is another type of combat methodology known as weapon-on-weapon methodologies, including heterogeneous Lanchester equations and killer-victim scoreboard methodologies.[2] The latter methodology, often referred to as KV scoreboards, derives its name from the use of a matrix in which the rows are the shooters and the columns are the targets in a specific battle. Each element of the matrix is the number of kills of that target by that type of shooter over a fixed assessment period. The ATCAL (attrition-calibration) and APP (antipotential/potential) methodologies are the two primary KV-scoreboard methodologies currently in use. These were developed, respectively, by the Army's Concepts Analysis Agency (CAA) and the Institute for Defense Analyses (IDA). Each uses many KV scoreboards both to calibrate its own complicated algorithms and to display the results of a specific combat situation.[3]

The strength of the KV-scoreboard methodologies is their detailed casualty distribution results that reflect the weapons and tactics of a high-resolution model. If the high-resolution model adequately represents radically different weapons and tactics, then the KV scoreboards will inherently reflect these factors in their calibration process.

KV-scoreboard methodologies are much more detailed than either traditional force-on-force methodologies or even the proposed SFS methodology. A different KV scoreboard is required for each type of engagement, type of terrain, unusual force mix, doctrine, training,

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[2]Two examples of heterogeneous Lanchester equation combat models are the German hierarchy of models built at the IABG, and the COBRA addition to the Corps Battle Simulation (CBS). The IABG models employ nonhomogeneous Lanchester equations that are calibrated to models sensitive to combined arms effects and explicitly include situations in infantry-favorable terrain and type battles. COBRA is a rule-based processor that modifies nonhomogeneous Lanchester equations in the CBS model to better account for combined arms and other factors that may affect combat effectiveness. Both of these models appear to adequately account for the basic combined arms effects.

[3]For a recent discussion of ATCAL and references to earlier material on both ATCAL and COSAGE, see U.S. Army Concepts Analysis Agency, *Attrition Calibration (ATCAL) Evaluation Phase I—Direct Fire (ATVAL Phase I)*, CAA-SR-91-10, July, 1991.

etc., creating large input data requirements. Each combat situation requires a different calibration board, and a large number of higher-resolution model runs are required to produce each calibration board. This demand for detailed input data requires that KV-scoreboard methodologies obtain a very large number of calibration boards or else run the risk of not accounting for many important combat factors, including combined arms effects.

For example, let us assume that a given KV-scoreboard methodology is calibrated to cases where there are no shortages of platforms or killing potential on each side. When there are fully combined arms forces engaged in assault-type battles, usually only artillery assets can kill other artillery assets, since the artillery assets are not considered "available" to other types of weapons. Now let us try to extrapolate to a case where the defending side has only artillery assets, while the attacking side has no artillery. The KV-scoreboard methodology will show that the attacker takes losses due to the defending artillery, while the defender takes no losses since their artillery is not "available" to the attacker's assets. In reality, the attacker would overrun the defender's artillery positions in the absence of defending maneuver elements. The traditional solution to this problem is to create another KV scoreboard to account for cases where there are insufficient maneuver forces to adequately protect one side's artillery assets.

However, there is a practical limit to the number of KV scoreboards and situations that can be addressed with this type of approach. Even when high-resolution models are run on fast machines, the true bottleneck lies in setting up, debugging, and analyzing the results of the detailed model's data inputs and outputs. As an alternative approach, one could account for variations from the detailed calibration cases using algorithms and judgment, rather than attempting to run all of the necessary cases with a high-resolution model. This alternative approach is the basis of the SFS methodology as applied to high-resolution models.

SOURCES OF CALIBRATION DATA

The SFS methodology is designed to be calibrated to whatever level of input data is available. If KV scoreboards are available, the SFS methodology will employ these scoreboards as inputs to the category multipliers, attrition, and casualty distribution processes. If such detailed input boards are not available, the SFS methodology will still be able to define KV-scoreboard type outputs using explicit assumptions. In this respect, the SFS methodology lies between the traditional force-on-force methodologies and the weapon-on-weapon methodologies. Using the same input boards as a KV-scoreboard methodology, SFS will produce the same KV-output board given the same number and types of assets engaged. The SFS methodology and the KV-scoreboard methodologies may be calibrated to the same points, but they will not extrapolate in the same manner. The SFS extrapolation methodology for casualty distribution is simpler and less detailed than either ATCAL or APP, and thus will not extrapolate away from the calibration boards in the same manner as either KV-scoreboard methodology. Of course, the SFS and other KV-scoreboard methodologies must assume that high-resolution combat models adequately account for combined arms effects; otherwise there is no sense calibrating the methodologies to these data sources in the first place. If this assumption is not valid, other sources of data must be considered.

There are three possible data sources to provide the numbers for an SFS methodology: military judgment, historical analysis, and calibration to more-detailed combat models.[4] This is essential since no one source of data provides sufficient information on the issues being examined. For example, military judgment is appropriate to account for more-qualitative factors that are well known but not well represented by quantitative models. The effects of training, nationality, morale, shock, surprise, and planning are just a few examples of more-qualitative effects. Similarly, history can provide a sanity check on the magnitudes of results, such as the intensity of combat by echelon and operational movement rates for different types of units. Detailed models may be better able to address more futuristic "what if" questions, especially when untraditional assets and tactics are employed. Military judgment is already part of all combat models inasmuch as if the results of any model are considered "unreasonable" by military standards, the model is "tweaked" and otherwise modified to obtain more "reasonable" results. The author recommends querying a panel of experts as to the values that should be used to better calibrate the SFS parameters beyond the values created by RAND and included in this paper. In addition, the SFS parameters defined by judgment should be compared with SFS parameters calibrated to outputs of higher-resolution combat models as they become available.

In addition, there is a need to perform basic sensitivity analysis to bound the magnitude of the effects of possible errors in the defined parameters. One problem with large quantities of detailed data is that it becomes much more difficult to perform sensitivity analysis. This problem is shared by both the SFS methodology and KV-scoreboard methodologies when detailed data are used. It is hoped that the ability of the SFS

[4]Using historical analysis alone runs into the converse of the problem faced by high-resolution models. In historical analysis, there are rarely enough cases with sufficient similarity to adequately cover the space of possible situations with a reasonable degree of certainty.

methodology to represent some of these effects in less detail will be useful for purposes of sensitivity analysis.

FILLING A NEED

One important point that needs to be raised explicitly is the tendency to assume that including more detail in a model is always better, regardless of the purpose of the model. It is true that aggregate models do not necessarily account for detailed effects, such as the benefit of a unit as a function of the type of terrain. Less well understood, however, is the corollary that detailed models do not necessarily account for aggregate effects. For example, one can drive a tank company an average of 25 miles per hour in one day, and a model resolved to company-level units will let many such companies drive that average speed all day. But a division movement rate averages only 10 miles per hour or less in one day, contrary to the results of the more-detailed model. The reason is that the more-detailed model is not accounting for aggregate effects sufficiently understood at the division level. Similarly, company-level combat attrition rates will be significantly different than division-level combat attrition rates. Divisional attrition rates are not just the sum of company-level attrition rates, but are defined by rates appropriate to the scope and echelon of combat. In a like manner, the SFS methodology attempts to account explicitly for the more-aggregate effects not well represented in more-detailed weapon-on-weapon attrition methodologies, as well as account for more-detailed effects not represented in more-aggregate models. It also seeks to define a context where the different combat arms can have a balanced representation, attempting to overcome the bias in favor of tanks and artillery (depending upon the scoring system used) in today's aggregate combat models.

The primary advantages of the proposed SFS methodology are: a) that the methodology is conceptually simple, relatively transparent and available for detailed review, and b) that the methodology works in the absence of more-detailed casualty distribution data. Regarding the point about simplicity, the methodology has been kept as simple as possible, relying on a set of short rules and calculations that require only addition, subtraction, multiplication, and division. All of the SFS parameters can be easily reviewed and varied, which enables it to be critiqued by the analytic community. The text documents the explicit assumptions used to ensure that all of the parameters were based upon a common framework in order to keep the subjective judgments within reasonable bounds and to preclude double-counting specific effects. The spreadsheets described in Appendix C and referred to in the Preface are available for such a review. We anticipate further improvements to the spreadsheets to enhance the ability to perform sensitivity analysis.

thereby making the SFS parameter review an easier process. The author expects discussion of the numbers will continue, especially as technology, tactics, and doctrine change over time.

Regarding the second point on more-detailed calibration data, such data may be used when available, but this is not a requirement. If one does not have the large number of KV scoreboards required to employ a traditional KV-scoreboard methodology, the SFS methodology is available to perform the analysis.

There are three known limitations to the existing SFS methodology. The first limitation is that when one is considering forces and tactics significantly different from those currently in existence, high-resolution simulation and gaming may be the preferred methods to use. Secondly, the SFS methodology is not designed for use in battalion-level or below simulations where line-of-sight calculations are being calculated. Thirdly, the current SFS does not adequately reflect some of the first-order effects of air forces on ground-force effectiveness (nor do any of the other combat models the author is familiar with). For example, although the SFS does include effects such as the ability of attack helicopters to mitigate shortages of armor or artillery capabilities, it does not reflect the consequences of local air superiority over the combat zone on ground combat effectiveness there. Correcting and integrating such synergistic effects is the first priority for SFS improvement.

ORGANIZATION OF THE DOCUMENT

The rest of this Note describes the SFS methodology and its current and planned applications in the RSAS (RAND Strategy Assessment System). The next section presents an overview of the four-stage process of the SFS methodology: varying asset strength as a function of the combat situation, varying the force strength as a function of asset mix, performing combat assessment, and calculating casualty distribution. The remaining sections present the details of these four stages. The final section presents some optional calculations that can be performed, including conserving scarce assets at the cost of reduced combat effectiveness, accounting for extreme differences between lethality and vulnerability, and accounting for different generations of armor and anti-armor assets.

In each section, the theory behind the methodology is presented, followed by a description of its application in the RSAS. The RSAS contains two theater models: CAMPAIGN-MT, representing Central Europe and Korea, and CAMPAIGN-ALT (also known as S-Land [Allen and Wilson, 1987]), representing all other land theaters. A version of the SFS methodology has been incorporated in the CAMPAIGN-ALT model. As part of CAMPAIGN-ALT, the SFS methodology has been applied in selected RAND studies and was used successfully during the 1991 Global Game at the U.S. Naval War College (see Appendix

D for an example). The SFS methodology will also be incorporated into the new RSAS integrated theater model later this year. Appendix A also describes a much less-detailed version of the SFS methodology for use in studies requiring less detail.

2. OVERVIEW OF METHODOLOGY

The SFS methodology involves four basic stages:

Varying the strength of each category of weapon as a function of the terrain and type of engagement.

Modifying category multipliers to account for shortages in the combined arms mix.

Calculating combat outcomes, including losses to each side and the FLOT movement rate.

Calculating the casualty distribution across each category of weapon.

A numerical example of the primary calculations of these four stages is presented in Tables 2.1 through 2.3. The first two stages are contained in the first table. Although only one side is shown in the example, these calculations must be performed for both sides in the battle. Even though the complete SFS methodology has been defined for six or more categories of weapons, only tanks, infantry, and artillery assets are used in this simplified example. Each of these steps requires basic calculations, with "if-then" type tests used between some of the stages to determine the values of the multipliers for each calculation; details of these "if-then" tests are presented in subsequent sections.

Table 2.1

Sample Precombat Calculations in the SFS Methodology [a]

	Calculation Step:	Categories of Weapons: Tanks	Inf	Arty	Total
1.	Number of Assets (input)	300	2000	200	
2.	Asset Score (multiplier from force scoring mechanism, WEI/WUV)[b]	1.0	0.05	1.0	
3.	Raw Category Strength Points (row 1 times row 2)	300	100	200	600
4.	Force Score Multipliers[c] (optional)	1.0	1.0	1.0	
5.	Base Category Strength Points (row 3 times row 4)	300	100	200	600
6.	Situational Category Multipliers (obtained from look-up table that varies by combat situation)	0.8	1.0	1.2	
7.	Situational Category Strength (row 5 times row 6)	240	100	240	580
8.	Shortage Category Multipliers (obtained from look-up tables that vary by combat situation)	0.8	1.0	1.0	
9.	Final Category Strength (row 7 times row 8)	192	100	240	532

[a]Includes first two stages of SFS calculations.

[b]If the scoring mechanism includes a category weight, it is assumed to be included in this multiplier. One may wish to override the existing category weights in a scoring methodology. If so, one is then required to make sure that the category multipliers are defined with this assumption in mind.

[c]Optional force multipliers to account for the effectiveness of the unit. For example, the RSAS employs multipliers for training, nationality, and cohesiveness to determine the effectiveness of the unit before combat.

Table 2.2

Sample Combat Calculations in the SFS Methodology

Calculation Step:
10. Determine force strength for each opposing side (from total of row 9, Table 2.1; 532 strength points in this example).
11. Calculate force ratio (attacker over defender).
12. Determine defender loss rate (DLR), exchange rate (ER), and FLOT movement rates from look-up tables that vary by type of battle and force ratio. In this case, this side took 8 percent losses in this battle.
13. Determine *final* category strength lost by each side (by multiplying loss rates of row 12 by total of row 9). In this case, 8 percent times 532 equals 42.5 final strength points. This will be used to determine total losses by category.

Table 2.3

Sample Postcombat Calculations in the SFS Methodology

Calculation Step	Categories of Weapons			Total
	Tanks	Inf	Arty	
14. Final Category Strength (from row 9, Table 2.1)	192	100	240	532
15. Category Loss Multiplier (from look-up table that varies by combat situation)	1.3	1.0	0.3	
16. Shortage Category Multipliers (from row 8, Table 2.1)	0.8	1.0	1.0	
17. Relative Category Losses (row 14 times row 15 divided by row 16)	312	100	72	484
18. Category Strength Lost (row 17 divided by row sum (484) times row 13 Table 2.2 (42.5)	27.4	8.8	6.3	42.5
19. Fractional Loss (row 18 divided by row 14)	14.3%	8.8%	3.4%	
20. Assets Lost by Category (row 19 times row 1, Table 2.1)	42.9	176	6.8	
Initial Number of Assets (row 1, Table 2.1)	300	2000	200	

3. VARYING ASSET STRENGTH

This section presents the details of the first seven steps described in Table 2.1. Starting with the number of assets in each weapon category in the force, three multipliers are applied to obtain the situational strength of each weapon category as a function of the combat situation. (The shortage multipliers are calculated and applied in the next section.) This section will also show how the multipliers are determined, the implications of these calculations, and how they have been implemented in the RSAS theater models.

STEP 1: START WITH THE NUMBER OF ASSETS IN THE FORCE

Note that the calculations begin with the number of assets in the force, and not something simpler, such as the types of units engaged. This much detail is needed because units lose assets at different rates; a unit may lose key assets early in the fight. Therefore, a unit may no longer have a sufficient number of assets of a specific type to perform combined arms operations.

For example, an infantry-heavy unit may initially contain a limited number of armor and anti-armor assets to perform combined arms missions. However, as the unit takes losses, these more-scarce resources may be significantly reduced while the strength of the unit as a whole may remain relatively high. As a result, the unit may be at 80 percent strength, but have no armor or anti-armor assets. Thus one should start calculations at the asset level. However, if a study requires less resolution, one can still use the type of unit as a reasonable approximation, as described in Appendix A.

The types of assets currently distinguished in the RSAS include:

- Tanks
- ARVs and IFVs (armored recon vehicles and infantry fighting vehicles)
- APCs (armored personnel carriers without antitank capability)
- Anti-armor weapons
- Other infantry assets (including mortars and small arms)
- Artillery, including MLRS (Multiple Launch Rocket System)
- Attack helicopters
- Air defense weapons

Of these weapons, the attack helicopters and air defense weapons are used in separate assessment steps from the other weapons. The remaining six weapon categories are combined into a force ratio for basic ground combat adjudication.

Work is currently ongoing to extend the RSAS weapon categories to include:

Armor:

- Tanks
- Infantry carrying armored vehicles with anti-armor weapons (e.g., Bradley or BMP; abbreviated an "IFV/anti-armor" herein)
- Other armor with anti-armor weapons (e.g., ITV or BRDM with AT-3; abbreviated an "ARV/anti-armor" herein)
- Other armor without anti-armor weapons (e.g., Ferret; abbreviated an "ARV" herein)
- Infantry carrying armored vehicles without anti-armor weapons (e.g., M-113 or BTR-50; abbreviated an "APC" herein)

Infantry:

- Long-range anti-armor weapons
- Short-range anti-armor weapons
- Mortars (under 100 mm)
- Small arms

Artillery:

- Self-propelled artillery and large mortars
- Towed artillery and large mortar

Other:

- Attack helicopters
- Air defense weapons

Table 2.1, for example, assumes that only tanks, infantry, and artillery assets were available for combat. Other models may have different categories of weapons, or may choose to group the same assets in different categories. The SFS methodology handles these differences by grouping the category of weapons into the three basic combined arms elements (armor, infantry, and artillery) in the second stage. Helicopters are included in part of this methodology but not in the aggregate ground combat scores because the RSAS assesses them separately from the rest of the aggregated ground combat adjudication. For example, the presence of attack helicopters can reduce or eliminate the effects of shortages in platforms or capabilities, as shown by example in Section 4. All of the attrition effects to ground units caused by attack helicopters and fixed-wing aircraft are accounted for in separate attrition algorithms that vary by target posture and the target unit asset holdings.

The number of assets available for combat is considered here to be only those assets that could actually be engaged in the assessment cycle of the simulation (e.g., four hours). Only divisions committed to the Forward Line of Troops (FLOT) are included (and only these affect the relevant force ratios). The maximum density of such units on the FLOT will depend on terrain and force component. This is approximated here by specifying "shoulder space constraints" separately for armor, infantry, and artillery systems. The baseline form of terrain is "mixed," and for that it is assumed that the *maximum* density of forces, for both attacker and defender (although defenders will typically be much less densely employed) is given by: [1]

Type of Terrain	Armor	Infantry	Artillery
Mixed	80 Veh/km	350 Inf/km	80 Tubes/km

These numbers assume accounting at the divisional (or independent brigade) level. Thus, a former Soviet MRD with about 600 armored vehicles would require a minimum of about 7.5 kilometers of mixed frontage to fit on-line (roughly consistent with the traditional Soviet planning factor of 6-10 km width for a divisional breakthrough sector[2]), while a U.S. heavy division with perhaps 1,100 armored vehicles would require a minimum of about 14 kilometers of mixed frontage to fit on-line.[3] The artillery numbers are short of the Soviet

[1]This approach replaces the one used earlier in CAMPAIGN-ALT, which determined the forces on line by using rules of thumb based on km per Equivalent Division (ED). This had the artifactual effect of penalizing the defender for modernization, since replacing vehicles one-for-one with more lethal versions would increase the EDs and thus decrease the number of divisions on line.

[2]See Allan S. Rehm and John F. Sloan, *Operational Level Norms*, Science Applications, Incorporated, SAI-84-041-FSRC, April 1984, p. 2.4.

[3]See Appendix C for some standard divisional equipment levels. Some assessments of theater combat still use battalions as the key accounting unit. An average heavy U.S. battalion has about 100 armored vehicles, and about four to five heavy battalions would fit on the front of a division; thus, if accounted at the battalion level, the 80 armored vehicles per kilometer limit would suggest that a heavy U.S. division would require about five to seven kilometers of frontage. This is clearly much too little frontage for a U.S. division. The RSAS counts all battalions in a division against this frontage requirement, including the reserves at brigade and division level. Thus, if accounting were to be done at some level other than division, the density figures in this chart would have to be adjusted (cut about

norms for a massed sector (over 100 artillery tubes per kilometer), but those norms refer to artillery able to reach the massed sector (some of which may be offset outside the sector but still able to reach it, given the range of artillery), and 80 tubes per kilometer of space is still difficult to achieve given Soviet spacing norms for artillery batteries.

In other types of terrain, maximum densities would be somewhat different, and it is assumed they can be approximated by applying multipliers to the mixed-terrain figures. The multipliers currently used in the RSAS are:[4]

Type of Terrain	*Armor*	*Infantry*	*Artillery*
Open	0.8	0.8	1.0
Mixed	1.0	1.0	1.0
Rough	0.5	0.8	0.8
Urban	0.4	1.2	0.7
Mountain	0.2	0.6	0.4

These figures are based on a variety of considerations. Most importantly, the figures for armor were chosen to be consistent with real-world force-employment planning in the old Central Region (e.g., in the Fulda corps sector, which we considered to be a basic case of "rough" terrain, only about 50 percent of the frontage was "usable" for armored components). The figure of 0.2 for "mountain" terrain emerged from map studies indicating that in most "normal" mountainous regions, there are significant roadways and valleys to be found. The other numbers in this table are less critical, but are at least qualitatively consistent with intuition and practice. A more-detailed study of these factors would be appropriate. Here, as elsewhere throughout the community, there is need for explicit efforts to inform aggregated models with results of higher-resolution studies and models.

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in half, for example, to yield an appropriate representation at the battalion level given the numbers shown here). Different levels of accounting units would also require adjustments to the attrition curves presented in Section 5.

[4]To clarify terms here, suppose that a sector is 100 km in width geographically, but that most of it is heavily forested, with perhaps 50 km being the sum of subsector widths with good highways, secondary roads, off-road mobility, and so on--essentially providing 50 km of width for armor operations. From the perspective of armor, then, this sector would be characterized as "rough" overall, even though the areas with roads might be open. Then, in assessing how much of the frontage could be used by armored components, one would use the 0.5 factor in the table. Note that this replaces the previous RSAS method (in CAMPAIGN-MT) of recording for each zone a geographic frontage and "militarily usable frontage"; moreover, the terrain adjustments in Table 3.1 below replace the CAMPAIGN-MT terrain adjustments by zone. The new method integrates treatment of terrain considerations in essentially one place, and attempts to avoid double-counting terrain effects, as our sensitivity analysis showed previous versions of the SFS methodology tended to do.

At first blush, the relative values for open terrain may appear incorrect. However, in modern warfare, shoulder space depends less on how much equipment can be squeezed onto a frontage statically than on how densely the sides are willing to employ forces given the opposing threat, the lethality of modern weapons, and the need to maneuver and use terrain to survive. Actual force employment would depend on the force's national doctrine and details of circumstance, but it is a reasonable assumption that armored forces and infantry operating on open terrain should ordinarily not be as dense as when operating in mixed terrain because of their vulnerability on open terrain (thus the values postulated here).

Note that the assumptions on shoulder space are important because if they change significantly, many of the other terrain-related multipliers herein (especially Table 3.3) would need to be altered.

STEP 2: ASSET SCORE FROM FORCE SCORING MECHANISM

This methodology assumes the use of an existing scoring methodology (such as WEI/WUV) that already defines a relative value between combat assets. RAND has been developing a new scoring methodology as part of the RSAS project, as summarized in Appendix E; these scores are used herein. If category weights (the WUVs in WEI/WUVs) are used in the scoring system, they are applied *at this step*.

For example, in the WEI/WUV scoring system, each type of asset has been given a value relative to all other types of assets in that category. In order to combine all of the categories of weapons into a total force score, a category weight is applied to each category of weapon before summing over all categories to obtain a total force score. If the scoring mechanism uses category weights, apply them at this step.

Note that most scoring systems apply these scores by type of weapon (e.g., a different value for M1 tanks than for T-54 tanks), and not by weapon class (e.g., tanks), which requires that Steps 2 and 3 be done at the weapon type level, and not at the weapon class level.

STEP 3: CALCULATE RAW CATEGORY STRENGTH POINTS

Multiplying the number of assets in each category by the value of each category of weapon results in the strength points associated with each category of weapon. The total raw strength points in the force are obtained by summing the strength points in each category.

In the RSAS, neither Step 2 nor Step 3 needs to be performed, since the result of Step 3 is stored by type of weapon in the RSAS database. The sum of these numbers is used to calculate the Equivalent Divisions (EDs) of a force.[5]

STEP 4: APPLY FORCE SCORE MULTIPLIERS

Force score multipliers are applied in the RSAS to account for some of the more-qualitative factors that influence combat effectiveness. Some of these factors include the effects of the unit's level of training, cohesiveness, or nationality. For example, if a unit has just been mobilized, it may not be as effective as a unit that has been active for a longer period of time. To account for this difference, the newly formed unit is degraded by a factor less than 1.

In the RSAS, the effective value of a combat unit is given by its effective equivalent division (EED) strength. This value is found by taking a unit's ED strength and multiplying it by the product of all of the qualitative factors (such as training, cohesiveness, and nationality). The EED strength of a unit is usually, but not always, less than or equal to its ED strength.

The SFS situational and shortage multipliers are applied to the assets of a force only after these other qualitative force multipliers have been applied. The reason is that 100 tanks in a poorly trained unit may not be as effective as 80 tanks in a well-trained unit. Therefore, the SFS methodology is applied to the number of effective assets in a given battle. In Table 2.1, all of the effectiveness multipliers of row 4 are equal to 1.0, and so have no effect in this example.

STEP 5: CALCULATE BASE CATEGORY STRENGTH POINTS

Rows 3 and 4 of Table 2.1 are multiplied to obtain the base strength points for each category of weapon (its EEDs). The total EED strength of a force is obtained by summing the strength points over all the categories of weapons.

Earlier combat assessment methodologies stopped their combat strength calculations at either Step 3 or this point, and moved straight into the combat adjudication process. The SFS methodology applies two more multipliers to each category of weapon before summing over all categories to obtain the final total force strength.

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[5]Since strength points represent a rather arbitrary measure, the concept of an "equivalent division" was created. The strength points of a specified division (a mid-'80s U.S. armored division) was used as the standard division, against which all other divisions were measured. The relative value of any other division was calculated by taking its strength points and dividing by the strength points of the standard division. For example, if the second division had a strength only 80 percent as large as the standard division, then the smaller division would have a value of 0.8 EDs.

STEP 6: DETERMINE SITUATIONAL CATEGORY MULTIPLIERS

This step of the SFS methodology can be presented very simply. We can develop two look-up tables, one for the attacker and one for the defender, as shown in Tables 3.1 and 3.2. Then, given the type of battle and the type of terrain, we can look up weapon category multipliers from each table. These situational category multipliers can then be multiplied onto the base category strength points, as shown in the example in Table 2.1.

In this step, however, we shall examine in detail the rationale for the multipliers themselves. Although much more involved than the simple look-up table approach used to apply the SFS process, the calibration process for the SFS parameters in the absence of high-resolution KV-scoreboard data is rather involved, as shown below.

The calibration process emerged from a RAND workshop of analysts held on March 20 and 21, 1991, and from data development and sensitivity testing thereafter. The description of Step 6 is now more lengthy and involved, but the underlying assumptions and factors are easier to discuss separately, and the current approach allows the user to decompose the SFS adjustments and consider the validity of each in a clearer framework. The approach described here is now the "official" version of the SFS methodology as implemented in RSAS 4.6, released in November 1991. A brief overview of the key assumptions, tables, and rules follows:

The first assumption is that the effects of terrain and type of battle could be considered almost independent from each other *for purposes of calibration*. During our discussions, it became clear that terrain and type of battle effects are not independent, but that the dependencies tend to occur in a few specific cases. It was decided that rules would be used to address the exceptions to the independence assumption whenever they were needed.

In particular, we found that the categories of weapons needed to distinguish between different armored vehicles with and without antitank and personnel-carrying capability, and between short-range and long-range antitank weapons. For example, long-range antitank weapons do not tend to perform well in urban terrain due to the long arming ranges. Furthermore, short-range antitank weapons can be used by the attacker against enemy bunkers when assaulting prepared and fortified defenses. As each exception was discussed, the rule and underlying assumption were recorded.

Table 3.1

Attacker Situational Category Multiplier

		Category of Weapon					
Type of Battle	Type of Terrain	att Tanks IFVs	att APCs	att LR atgms	att SR atgms	att inf	att arty
Breakthrough	Open	1.601	2.093	0.426	0.324	0.288	0.440
Breakthrough	Mixed	1.400	1.820	0.380	0.360	0.320	0.400
Breakthrough	Rough	1.260	1.638	0.787	0.972	0.864	0.810
Breakthrough	Urban	1.120	1.120	0.359	1.215	1.080	0.630
Breakthrough	Mount	1.120	1.456	0.718	1.296	1.152	0.720
Withdrawal	Open	1.380	1.794	0.532	0.405	0.360	0.550
Withdrawal	Mixed	1.200	1.560	0.475	0.450	0.400	0.500
Withdrawal	Rough	1.080	1.404	0.699	0.864	0.768	0.720
Withdrawal	Urban	0.960	0.960	0.319	1.080	0.960	0.560
Withdrawal	Mount	0.960	1.248	0.638	1.152	1.024	0.640
Delay	Open	1.150	1.495	0.638	0.486	0.432	0.660
Delay	Mixed	1.000	1.300	0.570	0.540	0.480	0.600
Delay	Rough	0.900	1.170	0.524	0.648	0.576	0.540
Delay	Urban	0.800	0.800	0.239	0.810	0.720	0.420
Delay	Mount	0.800	1.040	0.479	0.864	0.768	0.480
Hasty	Open	1.380	0.966	1.277	0.972	0.864	1.320
Hasty	Mixed	1.200	0.840	1.140	1.080	0.960	1.200
Hasty	Rough	1.080	0.756	1.049	1.296	1.152	1.080
Hasty	Urban	0.960	0.960	0.479	1.620	1.440	0.840
Hasty	Mount	0.960	0.672	0.958	1.728	1.536	0.960
Deliberate	Open	1.150	0.805	1.064	0.810	0.720	1.100
Deliberate	Mixed	1.000	0.700	0.950	0.900	0.800	1.000
Deliberate	Rough	0.900	0.630	0.874	1.080	0.960	0.900
Deliberate	Urban	0.800	0.800	0.399	1.350	1.200	0.700
Deliberate	Mount	0.800	0.560	0.798	1.440	1.280	0.800
Prepared	Open	1.093	0.765	1.011	1.013	0.684	1.045
Prepared	Mixed	0.950	0.665	0.903	1.125	0.760	0.950
Prepared	Rough	0.855	0.599	0.830	1.350	0.912	0.855
Prepared	Urban	0.760	0.760	0.379	1.688	1.140	0.665
Prepared	Mount	0.760	0.532	0.758	1.800	1.216	0.760
Fortified	Open	1.035	0.725	0.958	0.972	0.648	0.990
Fortified	Mixed	0.900	0.630	0.855	1.080	0.720	0.900
Fortified	Rough	0.810	0.567	0.787	1.296	0.864	0.810
Fortified	Urban	0.720	0.720	0.359	1.620	1.080	0.630
Fortified	Mount	0.720	0.504	0.718	1.728	1.152	0.720
Static	Open	0.920	0.920	0.560	0.450	0.450	1.320
Static	Mixed	0.800	0.800	0.500	0.500	0.500	1.200
Static	Rough	0.720	0.720	0.460	0.600	0.600	1.080
Static	Urban	0.640	0.640	0.210	0.750	0.750	0.840
Static	Mount	0.640	0.640	0.420	0.800	0.800	0.960
Meeting	Open	1.380	1.380	1.064	0.810	0.720	0.880
Meeting	Mixed	1.200	1.200	0.950	0.900	0.800	0.800
Meeting	Rough	1.080	1.080	0.874	1.080	0.960	0.720
Meeting	Urban	0.960	0.960	0.399	1.350	1.200	0.560
Meeting	Mount	0.960	0.960	0.798	1.440	1.280	0.640

Table 3.2

Defender Situational Category Multipliers

Type of Battle	Type of Terrain	Category def Tanks IFVs	def APCs	def LR atgms	def SR atgms	def inf	def arty
Breakthrough	Open	0.880	1.144	0.540	0.450	0.450	0.220
Breakthrough	Mixed	0.800	1.040	0.500	0.500	0.500	0.200
Breakthrough	Rough	0.720	0.936	0.460	0.600	0.600	0.180
Breakthrough	Urban	0.640	0.640	0.210	0.750	0.750	0.140
Breakthrough	Mount	0.640	0.832	0.420	0.800	0.800	0.160
Withdrawal	Open	0.990	1.287	0.648	0.540	0.540	0.550
Withdrawal	Mixed	0.900	1.170	0.600	0.600	0.600	0.500
Withdrawal	Rough	0.810	1.053	0.552	0.720	0.720	0.450
Withdrawal	Urban	0.720	0.720	0.252	0.900	0.900	0.350
Withdrawal	Mount	0.720	0.936	0.504	0.960	0.960	0.400
Delay	Open	1.210	1.573	0.756	0.630	0.630	0.880
Delay	Mixed	1.100	1.430	0.700	0.700	0.700	0.800
Delay	Rough	0.990	1.287	0.644	0.840	0.840	0.720
Delay	Urban	0.880	0.880	0.294	1.050	1.050	0.560
Delay	Mount	0.880	1.144	0.588	1.120	1.120	0.640
Hasty	Open	0.880	0.616	0.756	0.630	0.630	0.880
Hasty	Mixed	0.800	0.560	0.700	0.700	0.700	0.800
Hasty	Rough	0.720	0.504	0.644	0.840	0.840	0.720
Hasty	Urban	0.640	0.640	0.294	1.050	1.050	0.560
Hasty	Mount	0.640	0.448	0.588	1.120	1.120	0.640
Deliberate	Open	1.100	0.770	1.080	0.900	0.900	1.100
Deliberate	Mixed	1.000	0.700	1.000	1.000	1.000	1.000
Deliberate	Rough	0.900	0.630	0.920	1.200	1.200	0.900
Deliberate	Urban	0.800	0.800	0.420	1.500	1.500	0.700
Deliberate	Mount	0.800	0.560	0.840	1.600	1.600	0.800
Prepared	Open	1.210	0.847	1.404	1.170	1.170	1.210
Prepared	Mixed	1.100	0.770	1.300	1.300	1.300	1.100
Prepared	Rough	0.900	0.693	1.196	1.560	1.560	0.990
Prepared	Urban	0.880	0.880	0.546	1.950	1.950	0.770
Prepared	Mount	0.880	0.616	1.092	2.080	2.080	0.880
Fortified	Open	1.320	0.924	1.512	1.260	1.260	1.320
Fortified	Mixed	1.200	0.840	1.400	1.400	1.400	1.200
Fortified	Rough	1.080	0.756	1.288	1.680	1.680	1.080
Fortified	Urban	0.960	0.960	0.588	2.100	2.100	0.840
Fortified	Mount	0.960	0.672	1.176	2.240	2.240	0.960
Static	Open	0.550	0.550	0.378	0.315	0.315	0.825
Static	Mixed	0.500	0.500	0.350	0.350	0.350	0.750
Static	Rough	0.450	0.450	0.322	0.420	0.420	0.675
Static	Urban	0.400	0.400	0.147	0.525	0.525	0.525
Static	Mount	0.400	0.400	0.294	0.560	0.560	0.600
Meeting	Open	0.880	0.880	0.718	0.567	0.504	0.550
Meeting	Mixed	0.800	0.800	0.665	0.630	0.560	0.500
Meeting	Rough	0.720	0.720	0.612	0.756	0.672	0.450
Meeting	Urban	0.640	0.640	0.279	0.945	0.840	0.350
Meeting	Mount	0.640	0.640	0.559	1.008	0.896	0.400

A second important assumption (different from that of the earlier SFS methodology distributed in draft) is that *the base case will be considered to be a deliberate defense in mixed terrain at a roughly 2.5:1 raw force ratio* (i.e., the ratio of equipment scores).[6]

The current approach also includes *some* effects of aircraft in the SFS calculations. For example, attack helicopters can be used to compensate for a shortage of selected platforms and combat capabilities, as described in the next section. In addition, attrition caused by fixed-wing aircraft can selectively destroy specific categories of weapons.

Yet another important feature, not previously included in RSAS work, is explicitly representing the effects of attacker preparations (e.g., the days or weeks that attackers may use to assemble weapons and supplies for a high-intensity offensive). All categories of weapons are affected by the degree of preparation, as reflected by the combat intensity and exchange ratio multipliers. In addition, the attacker's artillery requires the most preparation to achieve proper siting, registration, coordination, and ammunition distribution and stockpiling. Rules for the effectiveness of the attacker's artillery as a function of the number of days of preparation have also been included.

With these related features included, the SFS methodology in the RSAS may look somewhat complex as described here, but the overall SFS methodology is still relatively simple in concept.

We hope to hold a second calibration conference, this time with additional participation from organizations outside of RAND. The conference would include a more-detailed Delphi process and the results of sensitivity tests to help tune these values. A precedent exists for using the Delphi methods to obtain some consensus on the category weights, since this is what was done to define the original WEI/WUV category weights. Much more sophisticated methods have become available in the last decade, including the Subjective Transfer Function (STF) methodology developed by RAND colleagues Clairice Veit

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[6]This choice is closely related to the famous "3:1 rule," according to which the attacker and defender suffer equal fractional loss rates at a 3:1 force ratio if the battle is in mixed terrain and the defender enjoys "prepared" defenses, by which we mean well-developed defenses to a depth of perhaps 10 or 20 km. Because a more typical battle arising in simulations involves deliberate defenses, where the break-even point would be a bit less (roughly 2.6 in the current RSAS attrition calculations), that case is treated as the baseline. Using this base case also facilitated calibrating the SFS parameters to the existing RSAS database, which had been developed over a period of some years based on a combination of historical analysis, comparisons with other well-documented models, and other considerations. Key sources included: Edward P. Kerlin, Donald W. Mader, and Dudley H. Edwards, *Computerized Quick Game: A Theater Level Combat Simulation*, Research Analysis Corporation, RAC-TP-266, Volume 1, November 1967; T. N. Dupuy, *Numbers, Predictions, and War: Using History to Evaluate Combat Factors and Predict the Outcome of Battles*, The Bobbs-Merrill Company, Inc., 1979; and T. N. Dupuy, *Contributing to the Reliability of the Army War College Model*, Historical Evaluation and Research Organization (HERO), November 1982.

and Monti Callero. An important alternative approach would be based on using high-resolution simulations to calibrate the SFS parameters, as discussed later in the Note. Unfortunately, considerable analysis is needed to determine how best to use the high-resolution simulations, since they do not always represent some of the important combined-arms effects the SFS seeks to capture, and since each simulation has its own intricacies and limitations. In addition, of course, there is a substantial cost, in terms of both money and priorities, to carry out a large number of appropriate high-resolution simulations. Nonetheless, this approach should be an important part of the effort to improve the SFS over time.

Defining Terrain and Terrain Multipliers

The situational category multipliers are obtained from a look-up table that varies by the combat situation. In the SFS methodology, we anticipated that the effects of the type of terrain and type of battle would not be independent of each other. In other words, the effects of terrain and type of battle might not be adequately described by applying a separate terrain multiplier and a separate type of battle multiplier. However, for ease of calibration, we have assumed that separate multipliers are an adequate approximation of these effects. The SFS methodology still applies, whether or not one assumes terrain and type of battle effects are dependent or independent.

Table 3.3 summarizes the multipliers with regard to type of terrain.[7] Note that these terrain-related multipliers are to be applied to those forces that can be employed after taking into account the shoulder-space limitations (also terrain-related) discussed above. These multipliers, then, deal with the terrain dependence of force lethality as a function of the terrain on which they are employed, assuming that they can indeed be employed. After controlling for shoulder-space constraints, the data in Table 3.3 suggest that as terrain

[7]An initial set of terrain and type battle multipliers emerged from the SFS workshop. My colleagues Bruce Bennett and Robert Howe then accepted the responsibility of an initial verification and validation of the numbers. They recognized that the terrain and type battle effects were nearly independent, and the methodology could therefore be decomposed into these two components for clarity of validation and understanding. They then developed initial values for each component, based upon a combination of historical analysis and the distinctly subjective assessments of the workshop. The subjective assessments were importantly constrained by requiring that the multipliers be 1.0 for the "base case" of mixed terrain and that the aggregate effect of the multipliers be roughly consistent with the terrain effects reported by Trevor Dupuy and others, and reflected in the community's existing theater-level models. They next sensitivity-tested the values, discovering that the terrain effects, in particular, were being double-counted (in shoulder space and in terrain multipliers). They then adjusted the values to produce more-reasonable results. As a result, the maximum "spread" of the numbers within Table 3.3 is relatively small, and the similarity between the attacker and defender multipliers is intentional, having given the defender an advantage factor of 2.5 in the base case.

becomes more difficult, armor, artillery, and attack helicopters tend to do more poorly, while infantry and air defense systems tend to do better.

Table 3.3

Situational Multipliers by Type of Terrain

Type	Attacker					Defender				
Terrain	Armor	Infty[a]	Arty	Helos[c]	Air Def[c]	Armor	Infty[a]	Arty	Helos[c]	Air Def[c]
Open	1.15	0.90	1.10	1.30	0.80	1.10	0.90	1.10	1.20	0.70
Mixed	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Rough	0.90	1.20	0.90	0.70	1.20	0.90	1.20	0.90	0.90	1.30
Urban	0.80	1.50	0.70	0.40	1.10	0.80	1.50	0.70	0.50	1.10
Mountain	0.80	1.60[b]	0.80	1.00[d]	1.50	0.80	1.60[b]	0.80	1.00[d]	2.00

[a]For short-range anti-armor systems and small arms; for long-range anti-armor systems, use:

Multiplier = 0.8 * armor-mult + 0.2

In the full spreadsheets, we have separate categories for short-range anti-armor, long-range anti-armor, and small arms. In this abbreviated table, we combined these separate columns into a single column, with exceptions defined by the preceding equation and the following rule: In urban areas, the long-range anti-armor score needs to be further multiplied by 0.5 because long-range anti-armor systems have a minimum arming range that works poorly in urban combat.

[b]Infantry specially trained in mountain warfare should get an additional multiplier of perhaps 1.3 here.

[c]Helicopters and ADA are not added to the force ratio but are assessed separately in the RSAS from other ground combat. However attack helicopters can reduce or eliminate a side's shortages of platforms and capabilities. In addition, the RSAS gives different effectiveness parameters for attacker and defender helicopters, which must be considered when analyzing these situational multipliers in the RSAS; the attacker's attack helicopters are considered half as effective as the defender's attack helicopters due to range and threat considerations. Air defense effectiveness in the RSAS differs by nationality but is not currently based upon which side is attacking.

[d]Attack helicopters in mountainous terrain have been given a multiplier of 1.0 as a compromise. They are actually more effective against armored vehicles but less effective against infantry in mountainous terrain. This issue will be revisited in a later version of the SFS methodology.

The five types of terrain in the SFS methodology have very different representations in CAMPAIGN-ALT and CAMPAIGN-MT. In CAMPAIGN-ALT, nine types of terrain are currently represented; these are mapped into the five SFS terrain types shown below. In CAMPAIGN-MT, terrain is defined in terms of a defensive strength multiplier (urban terrain is not currently represented in CAMPAIGN-MT). The correspondence between current terrain types and the SFS terrain types is:

Type of Terrain	ALT Terrain Type	MT Terrain Multiplier	
Open	Plains, Desert	>=1.0	but <=1.08
Mixed	Rural, Hilly	> 1.08	but <=1.14
Rough	Rough, Marsh	> 1.14	but <=1.2
Urban	Urban	N/A	
Mountain	Mountain, Confined	> 1.2	

The CAMPAIGN-MT terrain multiplier setting was traditionally defined as the defender's combat multiplier (across weapon types) when fighting in that type of terrain. In the SFS methodology, it is used as a threshold that distinguishes one type of terrain from another. For example, a CAMPAIGN-MT terrain multiplier of 1.10 corresponds to mixed terrain, while a terrain multiplier of 1.15 corresponds to rough terrain. Since the SFS methodology accounts for terrain effects explicitly, the CAMPAIGN-MT terrain multiplier is *not* applied to the defender in the force ratio calculations when the SFS methodology is being used.

Defining Type of Battle and Type of Battle Multipliers

The types of engagements represented in the SFS methodology are:

Covering Actions:

Breakthrough/Pursuit	Attacker has successfully penetrated defenses
Withdrawing	Defender withdrawing, enemy facing a blocking force
Delaying	Defender fighting, but purposefully trading space for time

Assaults:

Hasty defense	Defender has been in position only a short time
Deliberate defense	Defense positions built with organic resources
Prepared defense	Defense positions built with added resources
Fortified defense	Defender in substantial fortifications

Special Engagements:

Stalemate	Neither side attacking, local unit probing actions only
Meeting engagement	Both sides are in an attack posture

The top of the list is ranked from most attacker favorable (breakthrough/exploitation) to most defender favorable (fortified defense). Although the prioritization presented may be argued, the ranking does not matter with respect to the SFS methodology. This ranking only matters in assigning data values in Table 3.4 below.

Table 3.4 shows the basic situational multipliers for type of battle. The breakthrough and withdrawal values for the attacker differ by type of terrain because in rougher terrain, infantry and artillery must play the predominant role in pursuits, while in open or mixed terrain, infantry and artillery will likely play a much more passive role. The general pattern of the defender's covering force type of battle is to value the attacker's armor highest in a breakthrough, and to value the defender's armor highest in a delay. This is not to say that armor is not critical to the defender when countering breakthrough operations, but rather that the value of armor in such a case is less than its value in a delay, largely because the breakthrough battle is a much less cohesive battle for the defender.

Table 3.4

Situational Multipliers by Type of Battle

	Attacker					Defender				
Type Battle	Arm[b]	Infty[a]	Arty	Helos[c]	Air Def	Arm[b]	Infty	Arty	Helos[c]	Air Def
					Open/Mixed Terrain					
Breakthrough	1.40	0.40	0.40	1.80	0.70	0.80	0.50	0.50	0.80	0.40
Withdrawal	1.20	0.50	0.50	1.60	0.80	0.90	0.60	0.60	1.00	0.50
					Rough/Urban/Mountain Terrain					
Breakthrough	1.40	0.90	0.90	1.80	0.70	0.80	0.50	0.50	0.80	0.40
Withdrawal	1.20	0.80	0.80	1.60	0.80	0.90	0.60	0.60	1.00	0.50
					All Terrain Types					
Delay	1.00	0.60	0.60	1.40	0.80	1.10	0.70	0.70	1.20	0.70
Hasty	1.20	1.20	1.20	1.20	0.90	0.80	0.70	0.80	0.90	0.80
Deliberate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Prepared	0.95	0.95	0.95	0.90	1.10	1.10	1.30	1.10	1.10	1.10
Fortified	0.90	0.95	0.90	0.80	1.20	1.20	1.40	1.20	1.20	1.20
Stalemate[d]	0.80	0.50	1.20	0.50	1.10	0.50	0.35	0.75	0.35	0.70
Meeting[d]	1.20	1.00	0.80	1.00	0.80	0.80	0.70	0.50	0.70	0.50

[a]Add 0.3 to attacker short-range anti-armor weapons against prepared and fortified defenses.

[b]Both attacker and defender APC scores are multiplied by 1.3 for delay, withdrawal, and breakthrough, and by 0.7 for the assault cases.

[c]Helicopters and ADA are not added to the force ratio, but are assessed separately in the RSAS from other ground combat. The RSAS also gives different effectiveness parameters for attacker and defender helicopters, which must be considered when analyzing these situational multipliers.

[d]See explanation in later text regarding the values for stalemate and meeting multipliers.

Some may view the relative multipliers for the assault cases in Table 3.4 as showing too little difference between a hasty defense and a fortified defense. Three considerations led to this result:

1. The initial validation effort showed that the values proposed in the SFS workshop produced almost double the difference between these types of battle, compared to historical analyses. It appeared that the participants in the workshop applied nearly the full effect of the difference between these types of battle to both the attacker and the defender, leading the effect to be double-

counted. As a result of the validation effort, these differences were split between the attacker and defender, and the total effect returned to the historical pattern found in several previous analyses. Thus, in moving from a hasty to a fortified defense, the reduction in the strength of the attacking force compounds with an increase in strength of the defending force, significantly shifting the effective force ratio.

2. These parameters were calibrated so as to be consistent, in the aggregate, with prior RSAS treatment of terrain and type battle.
3. Differences drawn here will often be compounded in the shortage calculations in Section 4, and we wish to avoid double-counting (one of the more insidious complications of actually implementing the SFS approach).

The meeting and stalemate cases are somewhat artificial in the sense that the attacker is arbitrarily chosen as the stronger of the two sides. As a result, all calculations for these cases should be neutral to each side (rather than showing the significant defender advantage, as in the other cases). Thus, the values chosen in Table 3.4 for the attacker and defender are intended to offset the basic defender advantage before doing the shortage calculations. A further adjustment is required in Section 6 before doing the final combat adjudication.

The process of looking up a number in a table and applying it to each category of weapon is relatively straightforward. In the case of Tables 3.3 and 3.4, we assume that the same multipliers are applied to tanks, ARVs, and IFVs, while APCs employ a multiplier times the armor score for some types of battle. In applying Tables 3.3 and 3.4, we also divide the unarmored anti-armor assets into long-range and short-range assets. This division was necessary to account for the advantages and disadvantages of each of the two ranges depending upon the type of battle and type of terrain. For example, the relatively short line of sight in most urban terrain strongly favors short-range antitank assets and nearly precludes the use of long-range anti-armor assets with a large minimum arming distance.

Besides the factors discussed directly in Table 3.4, it is also necessary to adjust the attacker's infantry weapon values whenever a clear attacker can be identified. That is, the attacker in the covering force or assault battles and both sides in the meeting engagement require a further multiplier:

Type Weapon	Attack Infty Multiplier
Long-range anti-armor	0.95
Short-range anti-armor	0.90
Mortars	0.90
Small arms	0.80

This multiplier reflects the relative disadvantage of attacking with unarmored infantry weapons.

Sample SFS Calculations by Type of Unit

Several Microsoft Excel spreadsheets are available to assist in this tuning process. One set of spreadsheets supports calculations for the attacker, while the other set supports calculations for the defender. The spreadsheets can be used to identify the total product of Tables 3.3 and 3.4, the value of specific sample units as shown in Table 3.5,[8] and the relative fraction of a unit's strength in each category, depending upon the situation, as shown in Appendix C. For example, if a U.S. armored division has a value of 1.0 ED strength in a deliberate defense in mixed terrain, then it has a value of 0.59 EDs while in a fortified defense in mountainous terrain. (These examples use unclassified numbers for purposes of demonstration, and are not meant to be authoritative for actual unit strengths.) A U.S. light infantry division may have a 0.21 ED strength in mixed terrain in a deliberate defense, but it has a 0.40 ED strength in a fortified defense in mountainous terrain. Note that although the armored division strength decreased by about 40 percent between the deliberate defense in mixed terrain and fortified defense in mountainous terrain, the infantry unit's strength nearly doubled. One can see from Table 3.5 that combined arms units (like a Soviet MRD) have the least variance in strength over type of terrain and type of engagement (0.22 to 0.68

[8]In Table 3.5, each unit is assumed to have a basic combat frontage that is used to constrain weapon availability. The U.S. divisions are assumed to have a 25 km frontage in defense and a 20 kilometer frontage as an attacker. The Soviet units are assumed to have a 20 kilometer frontage as a defender and a 15 kilometer frontage as an attacker. Thus, as an attacker in mountainous terrain, the U.S. armored division would have 4 kilometers of armor-usable frontage (20 percent of 20 kilometers), upon which it could place 320 armored vehicles (80 vehicles per kilometer), or about 30 percent of its total armored strength. Only this 30 percent of the armor is included in these calculations. We have applied a constraint only on armor in generating Table 3.5.

Table 3.5

SFS Sample Calculations: Values for Standard Divisions

		Defender				Attacker			
Type of Battle	Type of Terrain	U.S. Armr Div	U.S. LID	Sov Tank Div	Sov MR Div	U.S. Armr Div	U.S. LID	Sov Tank Div	Sov MR Div
Breakthrough	Open	0.80	0.09	0.53	0.37	1.42	0.07	0.93	0.62
Breakthrough	Mixed	0.73	0.09	0.49	0.35	1.24	0.07	0.81	0.55
Breakthrough	Rough	0.62	0.11	0.45	0.33	0.94	0.18	0.73	0.61
Breakthrough	Urban	0.46	0.13	0.37	0.30	0.71	0.20	0.53	0.44
Breakthrough	Mount	0.28	0.14	0.22	0.22	0.46	0.22	0.35	0.36
Withdrawal	Open	0.93	0.12	0.62	0.45	1.24	0.09	0.82	0.56
Withdrawal	Mixed	0.86	0.12	0.57	0.42	1.09	0.09	0.72	0.50
Withdrawal	Rough	0.73	0.14	0.53	0.40	0.81	0.16	0.63	0.53
Withdrawal	Urban	0.55	0.16	0.43	0.36	0.61	0.18	0.46	0.38
Withdrawal	Mount	0.35	0.17	0.28	0.28	0.40	0.20	0.30	0.31
Delay	Open	1.16	0.15	0.77	0.57	1.07	0.10	0.71	0.50
Delay	Mixed	1.07	0.15	0.71	0.53	0.95	0.11	0.63	0.45
Delay	Rough	0.91	0.17	0.66	0.50	0.66	0.12	0.51	0.42
Delay	Urban	0.68	0.19	0.54	0.45	0.50	0.14	0.37	0.31
Delay	Mount	0.44	0.21	0.35	0.35	0.32	0.15	0.24	0.24
Hasty	Open	0.86	0.15	0.59	0.43	1.33	0.21	0.91	0.66
Hasty	Mixed	0.79	0.15	0.55	0.40	1.18	0.22	0.82	0.60
Hasty	Rough	0.68	0.17	0.51	0.39	0.86	0.24	0.68	0.57
Hasty	Urban	0.54	0.19	0.42	0.38	0.69	0.27	0.52	0.47
Hasty	Mount	0.36	0.21	0.29	0.29	0.48	0.30	0.37	0.39
Deliberate	Open	1.08	0.20	0.75	0.55	1.11	0.17	0.76	0.55
Deliberate	Mixed	1.00	0.21	0.69	0.52	0.98	0.18	0.68	0.50
Deliberate	Rough	0.87	0.24	0.65	0.50	0.72	0.20	0.57	0.48
Deliberate	Urban	0.69	0.27	0.54	0.49	0.57	0.23	0.43	0.39
Deliberate	Mount	0.47	0.29	0.37	0.39	0.40	0.25	0.31	0.33
Prepared	Open	1.21	0.25	0.84	0.63	1.06	0.17	0.73	0.53
Prepared	Mixed	1.12	0.26	0.78	0.60	0.94	0.18	0.65	0.48
Prepared	Rough	0.97	0.30	0.73	0.58	0.69	0.20	0.55	0.46
Prepared	Urban	0.79	0.35	0.62	0.58	0.56	0.22	0.42	0.38
Prepared	Mount	0.54	0.38	0.44	0.47	0.39	0.24	0.30	0.32
Fortified	Open	1.31	0.27	0.91	0.68	1.00	0.16	0.69	0.50
Fortified	Mixed	1.22	0.29	0.85	0.65	0.89	0.17	0.62	0.46
Fortified	Rough	1.06	0.32	0.79	0.63	0.65	0.19	0.52	0.44
Fortified	Urban	0.86	0.37	0.68	0.62	0.53	0.21	0.40	0.36
Fortified	Mount	0.59	0.40	0.47	0.51	0.37	0.23	0.29	0.31
Static	Open	0.57	0.09	0.39	0.29	0.94	0.14	0.64	0.48
Static	Mixed	0.52	0.09	0.36	0.27	0.83	0.14	0.57	0.43
Static	Rough	0.45	0.10	0.33	0.26	0.61	0.15	0.47	0.40
Static	Urban	0.35	0.11	0.27	0.24	0.47	0.16	0.35	0.31
Static	Mount	0.24	0.12	0.19	0.19	0.34	0.17	0.26	0.27
Meeting	Open	0.83	0.11	0.56	0.40	1.29	0.16	0.87	0.62
Meeting	Mixed	0.76	0.12	0.51	0.37	1.14	0.17	0.77	0.56
Meeting	Rough	0.65	0.13	0.48	0.36	0.82	0.19	0.64	0.53
Meeting	Urban	0.50	0.15	0.39	0.34	0.63	0.22	0.48	0.41
Meeting	Mount	0.32	0.17	0.25	0.25	0.42	0.24	0.32	0.34

EDs, or a factor of 3.1) while a unit whose strength is primarily in one branch, like a U.S. light infantry division, has the most variance (0.07 to 0.40 EDs, or a factor of 5.7).

Note that in the preceding table, there is little difference between the attacking and defending unit scores. This is because the RSAS uses combat results curves that are calibrated to a base case in which a 2.5:1 force ratio against a deliberate defense in mixed terrain will reduce both the attacking and defending force at roughly the same rate. One could, instead, calibrate the tables to fit a base case of a 1:1 force ratio in a meeting engagement in open terrain, as was done in the first draft of this document. The reason we changed to a 2.5:1 ratio in a deliberate defense was because many aggregate combat models were calibrated to approximately that ratio for that type of battle and type of terrain.

Percent of Force Strength by Category of Weapon

The spreadsheet also shows the fraction of the whole unit strength contributed by each category of weapon by type of unit and combat situation (see Appendix C). For example, a Soviet MRD defending in mixed terrain with prepared defenses has an armor (tank, ARV, IFV, APC) contribution of 55.3 percent of the unit strength, while infantry (small arms, light mortars, and light antitank assets) only contributes about 35.2 percent of strength. However, for the same unit in fortified mountain terrain, armor may contribute only 29.8 percent of the unit strength, while infantry contributes 48.8 percent of the unit strength (see Table C.5).

Attacker's Preparations

The RSAS list of battle types does not reflect differences in attacker's preparations (the list of battle types does distinguish between different degrees of defensive preparation). Prepared attacks tend to be more intense than are hasty attacks; in addition, the exchange ratio would be somewhat more favorable to the attacker due to extensive preparations, including reconnaissance, artillery preparation, engineer support, and overall planning and rehearsal. These effects might be captured by a table that will be used in Section 5 to modify defender's loss rate (intensity) and the exchange rate, such as:

Days of Attacker Preparation	Intensity Mult	Exchange Ratio Adjustment
More than 7	1.00	0.95
5 to 6	0.95	1.00
3 to 4	0.85	1.05
1 to 2	0.75	1.10
Less than 1	0.65	1.15

In addition, we need to vary the category multipliers for different degrees of attacker's preparation. In particular, the effectiveness of the attacker's artillery would be better in a prepared attack than in a hasty attack; thus, if the attacker had prepared for some number of days (prep_days):

$$\text{artillery\_mult} = \begin{cases} 0.9 + 0.02 * \text{prep\_days} & \text{prep\_days} <= 10 \\ = 1.1 & \text{prep\_days} > 10 \end{cases}$$

Unfortunately, we cannot simply calculate the number of preparation days based upon final preparations for war. In some theaters, there has been relatively modest preparation for war in peacetime, requiring attacker preparations in the last moments before war. In other theaters (such as Korea), both sides are arrayed in forward positions in peacetime, with artillery firing planned in some detail. Thus, each theater requires a "default value" of prep_days based upon the degree of preparation accomplished in peacetime, with preparations for war beginning from a potentially nonzero value.

Another factor affecting combat outcomes is the level of intensity with which each of these attacks is attempted. At the high end of intensity, the RSAS has traditionally allowed "intense" attacks in main attack areas for a limited period of time (a few days). At the low end of intensity, the RSAS has traditionally represented a separate pinning or holding attack, though in the future we believe that this should simply be represented as an adjustment to the intensity, exchange rate, and FLOT movement rates of the types of attacks listed above. Attack intensity is discussed further in Section 5.

STEP 7: CALCULATE SITUATIONAL CATEGORY STRENGTH

The situational category strength is calculated by multiplying rows 5 and 6 together, as shown in Table 2.1. The result is the strength contributed by each category of weapon as a function of terrain and type of battle, before any combined arms shortages are calculated. This completes the first of the four stages for determining situational force strengths.

4. ACCOUNTING FOR SHORTAGES IN THE FORCE MIX

STEP 8: DETERMINE SHORTAGE CATEGORY MULTIPLIERS

Now that we have arrived at the situational force strength by category of weapon, we determine the shortage category multipliers. These factors will be applied to the situational force strength by category of weapon, and then all of the category strengths are summed to determine the total unit strength for the combat assessment process. The application of the multiplier is easy once it is defined. Once again, defining the multiplier to use is the difficult part.

There are three parts to this determination:

- Mapping categories of weapons into the three basic combined arms by platform and killing potential,
- Determining whether or not a shortage exists in combined arms platforms or killing potential as a function of the combat situation, and
- Determining the multiplier associated with each shortage as a function of the combat situation.

The weapon categories used in the database are mapped into the three basic combined arms branches: armor, infantry, and artillery. This mapping will account for both the strength in the "platforms" of each category and the ability to kill enemy platforms of the opposing categories. For example, armor can kill other armor and infantry, but not artillery, except in special circumstances (such as a breakthrough or withdrawal). These mappings are presented in Tables 4.1 and 4.2.

For example, a U.S. unit with a score of 200 points in artillery would have 200 points in artillery capability (and none in armor or infantry capability), 80 points in anti-armor capability, 200 points in anti-infantry capability, and 140 points in anti-artillery capability.

Even though the RSAS assesses the effects of attack helicopters separately from the aggregate ground combat assessment, the presence of attack helicopters may reduce an apparent shortage. For example, the antitank capabilities of an attack helicopter are added primarily into the anti-armor strength of a force, and they are also included in the artillery and armor platform categories due to their suppressive effects and shock effects, respectively. Theoretically, air defense weapons could also be included in these tables, though their

Table 4.1

Mapping Categories of Weapons to Combined Arms Platforms

Categories of weapons	Platforms Armor	Soft	Arty
Tank	1	0	0
IFV/anti-armor	1	0	0
ARV/anti-armor	1	0	0
APC	1	0	0
ARV	1	0	0
Long-range anti-armor	0	1	0
Short-range anti-armor	0	1	0
Mortars (under 100mm)	0	1	0
Small arms	0	1	0
SP arty	0	0	1
Towed arty	0	0	1
Attack helicopters	0.3	0	0.5

NOTE: To find the strength in each platform category, multiply the strength of the category of weapon by the number in the appropriate column. Attack helicopters may be used to help compensate to some degree for a lack of armor and artillery.

contribution in these areas is less certain (for example, air defense guns are fired at opposing infantry only in selected situations), and thus they have been excluded for now.

The numbers in Table 4.2 are intended to reflect weapon capability, and not an allocation of fire. Thus, the artillery unit mentioned above has a total of 420 antipoints, but in an actual engagement would be able to apply only its 200 points against opposing forces, assuming an allocation of fire consistent with Table 6.1 below when doing the casualty distribution stage.

One factor that is apparent from Table 4.2 is that one is rarely short of antisoft capabilities. However, one can be short of infantry "platforms." Without infantry, one cannot take or hold terrain.[1] This is represented in the CAMPAIGN-ALT theaters as additional effects on combat results, such as specified changes in the FLOT. For example, an

[1]Procedures for holding terrain are a fundamental part of ground combat doctrine. While U.S. doctrine emphasizes the requirement for infantry to hold ground, some countries believe that armored forces are valuable in holding ground, especially key pieces of terrain. According to such doctrine, several tanks may be given the job of holding a bridge or a crossroads. However, such doctrine is actually equivalent to denial operations, where one denies enemy access to a key piece of terrain for a very limited period of time. A similar technique is defined in U.S. doctrine to employ artillery fires to deny enemy access to key terrain. Neither denial method allows one's own forces to use the key terrain—it merely denies enemy use of that terrain for a very limited period of time. A determined enemy will be able to force the assets denying the terrain to withdraw over any extended period of time. Therefore, although infantry is still the only asset that can take and hold terrain, one must be aware that other doctrines may define terrain denial operations by noninfantry assets, which are sometimes mistakenly considered as holding the terrain.

Table 4.2

Mapping Categories of Weapons to Combined Arms Capabilities

Categories of Weapons	Anti-armor	Anti-soft	Anti-arty	Notes
Attacker:				
Tank	1.0	0.8	0.0 (0.3)	Note 1
IFV/anti-armor	0.8	0.4	0.0 (0.2)	
ARV/anti-armor	0.8	0.3	0.0 (0.2)	
APC	0.05	0.3	0.0 (0.05)	
ARV	0.05	0.2	0.0 (0.05)	
Long-range anti-armor	1.0	0.05	0.0 (0.2)	
Short-range anti-armor	1.0	0.05	0.0 (0.05)	Note 2
Mortars (under 100mm)	0.05	1.0	0.0 (0.05)	
Small arms	0.02	1.0	0.0 (0.05)	
SP arty	0.4	1.0	0.0-0.7	Note 3
Twd arty	0.3	1.0	0.0-0.7	
Attack helicopters	0.8	0.5	0.4	
Defender:				
Tank	1.0	0.8	0.0 (0.1)	Note 1
IFV/anti-armor	0.8	0.4	0.0 (0.1)	
ARV/anti-armor	0.8	0.3	0.0 (0.1)	
APC	0.05	0.3	0.0	
ARV	0.05	0.2	0.0	
Long-range anti-armor	1.0	0.05	0.0 (0.05)	
Short-range anti-armor	1.0	0.05	0.0	
Mortars (under 100mm)	0.05	1.0	0.0	
Small arms	0.02	1.0	0.0	
SP arty	0.4	1.0	0.0-0.7	Note 3
Twd arty	0.3	1.0	0.0-0.7	
Attack helicopters	0.8	0.5	0.4	

NOTE 1: The numbers in parentheses apply only in breakthrough or withdrawal cases, to account for maneuver assets overtaking defending artillery assets or attacking artillery assets being counterattacked by bypassed defending maneuver units. Multiply these numbers by 0.5 to better reflect artillery losses in the withdrawal case.

NOTE 2: Use 0.2 for attacker short-range antitank assets against soft targets when assaulting prepared and fortified defenses. This reflects the bunker-killing capability of light antitank weapons.

NOTE 3: The anti-artillery value depends upon the counterbattery capability, such as counterbattery radars and automated fire control systems. Use a base value of 0.7 for U.S. counterbattery capabilities, and reduce proportionally to a minimum of 0.0 for other nations.

attacking unit without infantry might be able to penetrate with armored forces into rear areas of the defender, advancing the FLOT but not the area controlled by the attacker. While the current version of CAMPAIGN-ALT treats the FLOT as the area controlled, the future RSAS Integrated Theater Model will treat these two concepts separately. (See the on-line documentation on these effects in the CAMPAIGN-ALT model.)

Given the strength in each category of platform and category of ability, one then determines whether or not there are any shortages as a function of the combat situation. In this section, we will include the concept of "density" as described in Soviet doctrine (Renznichenko, 1987). In this concept, the Soviets define a desired density of assets in a given area that is required to accomplish the mission. This concept will be used to determine whether there are enough platforms to fight a combined arms operation w'th this mix of weapons in this combat situation. For example, the Soviets may define a minimum anti-armor density of 30 assets per square kilometer. The RSAS model does not keep track of density per se, but it does keep track of frontage. Even though not all battles have been or will be linear in the future, this frontage is used as a surrogate for a square kilometer density. The factors discussed in Section 3 for limiting shoulder space are effectively applied to the true frontage to determine a militarily usable frontage for armor, infantry, and artillery. For example, if a unit is deployed across 50 kilometers of frontage in rough terrain, there should be roughly 20 kilometers of armor-usable terrain.

The procedure for determining whether or not a shortage exists in a platform is as follows: For each category of platform, compare it to a shortage threshold shown in Table 4.3 that defines the minimum density in strength per kilometer of usable frontage.
In the RSAS, this strength is given in situationally adjusted EDs (SEDs), the result of Step 7. For example, a full-strength U.S. armored division in deliberate defenses in mixed terrain has 5268.4 strength points, which equate to a strength of 1.0 SEDs by definition. Therefore, 3000 strength points of armor would equate to 0.569 SEDs or armor. (See Appendix C for the calculations of the strength points in the standard division.) In the example discussed in the previous paragraph, a unit operating on 20 kilometers of armor-usable terrain assaulting a

Table 4.3

Capability (SED/Usable km) Density Requirements

		Attacker			Defender		
Terrain	Type of Battle	Armor	Soft	Arty	Armor	Soft	Arty
Open	Assault	0.025	0.003	0.008	0.015	0.002	0.005
Mixed	Assault	0.025	0.003	0.008	0.015	0.002	0.005
Rough	Assault	0.015	0.006	0.007	0.010	0.004	0.004
Urban	Assault	—	0.008	0.004	—	0.0055	0.0025
Mntn	Assault	—	0.008	0.004	—	0.0055	0.0025
Open	Hsty/Mtg/Stm	0.025	0.0015	0.004	0.015	0.001	0.0025
Mixed	Hsty/Mtg/Stm	0.025	0.0015	0.004	0.015	0.001	0.0025
Rough	Hsty/Mtg/Stm	0.015	0.003	0.0035	0.010	0.002	0.002
Urban	Hsty/Mtg/Stm	—	0.004	0.002	—	0.003	0.0012
Mntn	Hsty/Mtg/Stm	—	0.004	0.002	—	0.003	0.0012
Open	Dly/Wth/Brk	0.025	0.001	0.0016	0.015	0.0005	0.0015
Mixed	Dly/Wth/Brk	0.025	0.001	0.0016	0.015	0.0005	0.0015
Rough	Dly/Wth/Brk	0.015	0.002	0.0014	0.010	0.0010	0.0012
Urban	Dly/Wth/Brk	—	0.0025	0.0008	—	0.0015	0.0008
Mntn	Dly/Wth/Brk	—	0.0025	0.0008	—	0.0015	0.0008

Dly/Wth/Brk are Delay, Withdraw, and Breakthrough type of battle cases; Hsty/Mtg/Stm are hasty, Stalemate, and Meeting; and Assault are all other cases.

force in prepared defenses would require 0.30 SEDs of armor to meet the density requirement. The values in Table 4.3 may also vary by theater, if so desired.

If a force does not have sufficient strength in a category of platform in the area of operations, then a penalty is applied. This penalty (short_mult) is of the form:

$$\text{short\_mult} = \frac{\text{short\_base} + \dfrac{\text{Level}}{\text{Required}}}{\text{short\_base} + 1}$$

where "short_base" is the base shortage value defined in Table 4.4, "Level" is the density of weapons systems present, and "Required" is the weapon system density from Table 4.3. For example, if an attacker on open terrain has half as much armor as required:

$$\text{short\_mult} = \frac{0.2 + 0.5}{0.2 + 1.0} = 0.58,$$

which would be applied against the attacker's infantry values. The reason for degrading the infantry is that in close combat, armor and infantry provide mutual support; a shortage in one reduces the effectiveness of the other. The size of the the multiplier is proportional to the degree of shortage.

The SFS methodology employs two alternative ways to assess situations where both sides have shortages in the same combat platform. The current methodology applies the standard shortage multipliers to each side and assesses combat as usual. This methodology automatically distributes the losses only to categories of weapons participating in the battle. Alternatively, the user can choose to set the methodology so that no shortage multiplier is applied when both sides have shortages in the same platform. For example, given only infantry and artillery on each side, one might not apply the armor shortage multipliers but rather increase the combat intensity to better reflect the resulting type of battle.[2] We plan to implement the latter alternative of the SFS methodology in the RSAS.

[2]For example, in Korea, infantry is the arm of choice for assaults and defenses in the forward areas, with artillery playing a major role in these engagements. The lack of armor to protect the infantry and the large amounts of artillery present suggest that attrition should be much higher than one would expect in a European case. (Our early efforts at calibration suggest that attrition rates may be, relatively, two to four times higher.) We have not yet developed a generalized formulation for these differences.

Table 4.4

Capability Shortage Multiplier Base

	Attacker			Defender		
Terrain	Armor	Soft	Arty	Armor	Soft	Arty
Open	0.2	0.6	0.2	0.4	0.6	0.2
Mixed	0.2	0.6	0.2	0.5	0.6	0.2
Rough	0.6	0.4	0.4	0.7	0.4	0.4
Urban	0.8	0.2	0.6	0.8	0.2	0.6
Mntn	0.8	0.2	0.6	0.8	0.2	0.6
Applied to:	Soft	Armor	Armor Soft	Soft	Armor	Armor Soft

Shortages in antiplatform abilities are calculated in a similar manner as platform shortages, but based upon a requirement relative to the capability of the opponent. For example, if one side is short of anti-armor capability, but the opposing side does not have much armor, then a shortage of anti-armor strength has no effect in this situation. Therefore, this shortage is calculated based upon a minimum ratio of ability to opposing platform strength. In most cases, a simple one-to-one ratio is a sufficient test. The shortage ratios used in the RSAS are shown in Table 4.5.

If a force does not have sufficient strength in a category of antiplatform ability, then another penalty is assessed. The penalty is calculated in the same manner as the capability

Table 4.5

Anticapability Shortage Ratio Requirements

		Attacker Anti-			Defender Anti-		
Terrain	Type of Battle	Armor	Soft	Arty	Armor	Soft	Arty
Open	Assault	2.0	2.0	0.5	0.5	1.0	0.2
Mixed	Assault	2.0	2.0	0.5	0.5	1.0	0.2
Rough	Assault	1.5	2.0	0.5	0.4	1.0	0.2
Urban	Assault	1.0	2.0	0.5	0.3	1.0	0.2
Mntn	Assault	1.0	2.0	0.5	0.3	1.0	0.2
Open	Hsty/Mtg/Stm	2.0	1.0	0.25	0.5	1.0	0.2
Mixed	Hsty/Mtg/Stm	2.0	1.0	0.25	0.5	1.0	0.2
Rough	Hsty/Mtg/Stm	1.5	1.0	0.25	0.4	1.0	0.2
Urban	Hsty/Mtg/Stm	1.0	1.0	0.25	0.3	1.0	0.2
Mntn	Hsty/Mtg/Stm	1.0	1.0	0.25	0.3	1.0	0.2
Open	Dly/Wth/Brk	2.0	0.6	0.1	0.5	0.5	0.1
Mixed	Dly/Wth/Brk	2.0	0.6	0.1	0.5	0.5	0.1
Rough	Dly/Wth/Brk	1.5	0.6	0.1	0.4	0.5	0.1
Urban	Dly/Wth/Brk	1.0	0.6	0.1	0.3	0.5	0.1
Mntn	Dly/Wth/Brk	1.0	0.6	0.1	0.3	0.5	0.1

penalty (based upon the short_base values in Table 4.4 above), but is used as a divisor of the *opposing* category of platform. For example, if the force is on the defense in open terrain and has half the required anti-armor strength, then the *enemy's* armor strength is divided by 0.58 (nearly doubling it). The rationale is that if one side is short of anti-armor capability, then the opposing side's armor will be more effective. This will have two results. First, the opposing side will be more effective and therefore have a greater strength, giving it a higher force ratio. This leads to a higher loss rate for the side with the shortage and a lower loss rate for the opposing side. Secondly, the casualty distribution calculations (described in Section 6) will result in fewer armor losses on the opposing side.

There are also other effects of shortages that are not well represented by multipliers on the strengths of categories of platforms. For example, some effects may make a breakthrough more probable, or allow an Operational Maneuver Group (OMG) to be more easily inserted. Some of these additional effects have been included in the CAMPAIGN-ALT theaters, since some unique features are associated with the flank theaters (see CAMPAIGN-ALT on-line documentation for the implementation of these additional effects). The more important effects are summarized briefly in Table 4.6.

Table 4.6

Other Effects of Shortages

Defender is short of armor:	Breakthroughs can occur more easily because defender cannot react quickly. (Multiply effective frontage of defender by 1.25.)
Attacker is short of armor:	Reduced FLOT movement rate. (Multiply FLOT movement rate by 0.75.) Breakthrough less likely to occur if enemy has sufficient armor. (Multiply effective frontage of defender by 0.8.)
Defender is short of infantry:	Can't hold terrain. May be forced out of prepared positions and into a delay. (Multiply effective frontage of defender by 1.25.)
Attacker is short of infantry:	Can't take terrain, but can insert OMG or other armored force instead if breakthrough conditions assessed (not yet implemented).
Defender is short of artillery:	Breakthrough more likely because can't mass fires quickly (not yet implemented).
Defender is short of anti-armor:	Overrun may occur in open terrain without prepared positions (not yet implemented).
Attacker is short of anti-armor:	No breakthrough may occur if defender has sufficient armor (not yet implemented).
Defender is short of antisoft:	Can't hold terrain if attacker has sufficient infantry (not yet implemented).
Attacker is short of antisoft:	FLOT will not move. (FLOT movement rate set to 0.)

Note that this accounts for effects such as "only infantry can take and hold terrain." According to these rules, a force consisting almost entirely of artillery or armor will not be able to take or hold terrain, no matter how strong it is. An armor-heavy force may be able to penetrate deep into enemy territory, but its lines of communications are not secure. A defending force consisting only of artillery will have a breakthrough assessed against it, thereby precluding the type of unrealistic situation described in the summary and introduction.

STEP 9: CALCULATE FINAL CATEGORY STRENGTHS

As mentioned earlier, the final category strengths are calculated by multiplying row 7 by row 8 in Table 2.1. The total unit strength in this combat situation is given by the total of row 9 (the sum of strengths over all categories). This value is used in the combat assessment process to determine losses on each side.

To illustrate the overall shortage multiplier, assume we have an attacking force with a force ratio of 2:1 after Step 7, operating against a deliberate defense in urban terrain. Let us assume that the defending force consists entirely of 580 strength points of infantry, and no armor or artillery strength points. The resulting strength distribution by category of weapon might be:

	Armor	Inf	Arty	Total
Defender force strength	0	580	0	580
Attacking force strength	480	200	480	1160

There is no capability requirement for armor in urban terrain, but the capability requirement for artillery will lead to a .38 multiplier (since the defender has no artillery at all, and the short_base is 0.6).

Let us further assume that the defender's infantry has no anti-armor nor anti-artillery capability, giving it divisors of .47 and .38 for the attacker's armor and artillery, respectively. The resulting force strengths are:

	Armor	Inf	Arty	Total
Defender force strength	0	220	0	220
Attacking force strength	1021	200	1297	2518

The new force ratio is 11.4:1, rather than 2:1. In addition, if the defending force is in open terrain without prepared defenses, it may be overrun and isolated, as described in Table

4.6. In the current version of the RSAS, a breakthrough would be assessed against the defender, thereby causing an additional fraction of the force to be lost due to encirclement. (Although this is currently performed as a one-time penalty, the RSAS could be adjusted to include a category for "isolated" forces on an axis so that the effects of encirclement could be explicitly addressed.)

Now let us assume that the defending infantry force was actually reinforced by a significant number of attack helicopters. From Table 4.2, we find that if there are a sufficient number of attack helicopters, this will compensate for the lack of artillery on the defending side, and therefore the 0.38 platform shortage multiplier would not be applied. In a similar manner, if there are enough attack helicopters, the defending force will not be short of either anti-armor or anti-artillery capabilities. Therefore, the force ratio in this latter case with attack helicopters on the defending side would be assessed at a 2:1 force ratio.

Note that even if there were not enough attack helicopters to completely mitigate the effects of platform and capabilities shortages, the presence of the attack helicopters would reduce the effects of the shortages on the defending side, thereby reducing the effective force ratio. Although the attrition caused by the attack helicopters is assessed in the RSAS separately from the ground combat attrition, the presence of the attack helicopters does affect the combined arms capabilities of the force to which they are attached. See Appendix F for a detailed example of the effects of shortages for different types of units in different types of terrain, with and without the presence of attack helicopters.

Many steps are involved in defining the shortages and determining their effects—perhaps more than are worthwhile. That is one reason why these calculations were skipped in the Central European theater, since such shortages would probably occur only rarely until late in the war, or in the event of very extreme arms control measures. We should keep in mind, however, that when those rare cases do occur, the effects are likely to be extreme, with whole units being overrun and a corps sector collapsing in a breakthrough. Even though such shortages may be rare in a Central Region conflict, they are likely to be more common in other theaters of operation. Therefore, the CAMPAIGN-ALT theaters tend to be more concerned about these shortages than CAMPAIGN-MT.

5. COMBAT ASSESSMENT

STEP 10: DETERMINE FORCE STRENGTH

Once we have determined the final situational strength by category of platform, we sum the strength of each category to obtain a total force strength for each side. This can be obtained from row 9, Table 2.1.

STEP 11: CALCULATE FORCE RATIO

The ratio of the attacking force strength to the defending force strength is the force ratio—or, better, the "situationally adjusted" or "modified" force ratio (MFR). The force ratio and the type of battle together determine the loss rates for each side and the FLOT movement rate. In addition, if changes in the phase of battle are identified (such as a breakthrough occurring due to special conditions), these changes are assessed as well, as described in the previous section.

The factors in Section 3 establish an appropriate force ratio for all but two types of battle. Both the meeting engagement and the stalemate type of battle assume that the attacker is the more powerful of the two sides as a convenience to doing the calculations, whereas in reality both sides are acting similarly and therefore neither should gain a defensive advantage. To overcome the normally assumed defender advantage, and given the other parameters in Section 3, it follows that the force ratio must be multiplied by 1.7 at this point for stalemates and meeting engagements.

The previous versions of the RSAS usually applied two factors to the force ratio calculation: adjustments for surprise and terrain. The new methodology still includes the surprise adjustment (independent of the SFS methodology), but the terrain factor is dropped because terrain effects are now incorporated in the adjusted force strengths that go into the force ratio calculation. As a further adjustment to previous versions of the RSAS, surprise is represented as a multiplier (less than 1.0) of the defender's strength, reflecting the fact that surprise tends to degrade the defender's performance, rather than improve the attacker's performance. Thus, $MFR = A' / (surprise * D')$, where A' and D' are the situationally adjusted force strengths and surprise is an optional analyst specified multiplier for surprise effects (often applied for only a short period of time).

STEP 12: DETERMINE LOSS AND MOVEMENT RATES

The first step in determining the loss and movement rates is determining the intensity of the attack. As suggested in Section 3, the attacker is able to determine the level of attack intensity appropriate to each sector. We use three "levels of intensity" in this methodology to represent these differences: (1) low, (2) medium, and (3) high. Medium intensity is the nominal intensity for attacks. High intensity occurs for a limited period of time (usually a couple of days) in main attacks when a minimum force ratio exists. Low intensity reflects a pinning attack (which should be called a holding attack according to U.S. Army doctrine); the purpose of the holding attack is to fix the defender in place while making the main attack elsewhere. The previous version of the RSAS represented only one type of holding attack. The new version represents a different type of holding attack for each type of assault (hasty, deliberate, prepared, and fortified) and for delay, withdrawal, and breakthrough. Intensity is irrelevant to a stalemate (static) situation because it is already assumed to be a low-intensity engagement. For meeting engagements, the intensity should be the higher of the two values set by either side. Intensity will affect combat outcomes as follows:

	Attack Intensity Parameter Multipliers		
Battle Intensity	DLR-Intens	ER-Intens	FMR-Intens
Low	0.3	1.2	0.2
Medium	1.0	1.0	1.0
High	1.5	1.0	1.5

That is, low intensity reduces both loss rates and movement rate. Meanwhile, since the attacker is not as effectively applying his forces at low intensity (holding attacks), he suffers a somewhat higher exchange ratio as a result. Although merely approximate, these multipliers are in qualitative accord with historical data.[1]

The RSAS has three different formulas for defining the outcomes of battle. These define the defender's loss rate (DLR), the exchange rate (ER′), and the FLOT movement rate (FMR). The equations are either piecewise linear or algebraic, depending on the analyst's preference. In the algebraic form, the defender's loss rate and the exchange rate are functions of the type of battle and the force ratio modified by all the situational factors. Importantly, in the new formulation, ER′ is the ratio of attacker and defender losses of *situationally adjusted strength*, not the "normal" exchange ratio, which is the ratio of attacker and defender equipment losses.[2]

[1]The effect of high intensity is identified as about a 90 percent increase in casualties during the first day only in Dept. of Army, *Staff Officers' Field Manual: Organization*, Technical, and Logistical Data, FM 101-10, Jan. 1966. Other sources of data suggest a smaller increase over a longer period of time, which we have chosen to employ.

[2]The need to distinguish between ER and ER′ was pointed out by Paul Davis, who also notes that while DLR, ALR, and RLR (the ratio of loss rates given by ALR/DLR) are the same for equipment

DLR = *intensity* * .03 * MFR^0.64
ER ´ = ER-Intens * 4.5 * MFR^(-0.57)

The attacker's loss rate (ALR) is required by consistency to be given by:[3]

ALR = (DLR * ER ´)/MFR

The overall attrition related intensity (*intensity*) is:

intensity = Bat-Intensity * Intensity-Prep-Mult * DLR-Intens

and the type of battle intensity factors (Bat-Intensity) are:

Type of Battle	Bat-Intensity
Withdrawing	1.05
Breakthrough	1.05
Delaying	1.00
Stalemate	0.10
Hasty defense	1.05
Deliberate def	1.00
Prepared def	0.95
Fortified def	0.80
Meeting	0.85

These values were derived by curve fits to traditional attrition curves for the indicated types of battle, and expert opinion in the case of some battle types not included in the

strengths and situationally adjusted strengths, ER and ER ´ differ by the ratio FR/MFR, where FR is the equipment-strength force ratio.

[3]The basis for these expressions for DLR, ER, and ALR are documented in unpublished work by Paul Davis and the author in the mid-1980s, and by subsequent internal project notes. In essence, they derive from: (a) seeking agreement with historical data on aggregated intensity of war (loss rates, as experienced in WW II and the 1967 and 1973 Mid-East wars); (b) requiring the 3:1 rule (i.e., that the attacker and defender would suffer equal loss rates at an equipment force ratio of 3:1 in prepared defenses and mixed terrain), which is roughly the same as the 2.5:1 rule we use here for the base case of deliberate defenses; (c) representing explicitly the tendency for initial battles in operations to be substantially more intense, with roughly 80 percent of the losses occurring in the first three days of a campaign taking perhaps ten days overall; (d) seeking something like a Lanchester-square law, but one modified to be a less dramatic function of force ratio (in part because in the real world, at this level of aggregation, the forces have the opportunity to control loss rates by withdrawal within a simulation time period); and (e) approximate consistency with previous RAND combat simulations' assumptions about the shapes of the related curves (which in large part derived from previous work by the Research Analysis Corporation (RAC) and the Historical Evaluation and Research Organization (HERO). There has been no effort to date to calibrate these equations or their parameters to results of high-resolution simulation. That could and should be done in the future.

historical literature. Since they directly affect the DLR, it is important to note that they are not an overall intensity measure; thus, a fortified defense, in similar circumstances, will suffer a lower loss rate than a hasty defense because of Bat-Intensity, while the ALR will be higher in attacking a fortified as opposed to a hasty defense.

The FLOT Movement Rate is a function of the type of battle and the relative attrition rates:[4] The attrition rates include the effects of attrition from attack helicopters and tactical aircraft, or:

$$DLR' = DLR + dlr(helos) + dlr(tacair)$$
$$ALR' = ALR + alr(helos) + alr(tacair)$$

Then, the base value of FLOT movement rate (FMR-base) is calculated by type of battle as:

Type of Battle	FMR-Base
Breakthrough	(30.0 + 5.0 * (DLR′/ALR′))
Withdrawing	(40.0 + 6.0 * (DLR′/ALR′))
Delaying	(10.0 + 18.0 * (DLR′/ALR′))
Hasty	(0.0 + 9.0 * (DLR′/ALR′))
Deliberate	(0.0 + 12.5 * (DLR′/ALR′))
Prepared	(0.0 + 12.0 * (DLR′/ALR′))
Fortified	(-0.5 + 10.0 * (DLR′/ALR′))
Meeting	(0.0 + 5.0 * (DLR′/ALR′))
Stalemate	0

This is then combined with the intensity multiplier:

$$FMR = FMR\text{-}Intens * FMR\text{-}base$$

Note that while this expression suggests that the FLOT movement rate increases with intensity, the intensity factor FMR-Intens is really a measure of the attacker's priority for movement on the particular sector and not a measure of the overall battle intensity. In typical simulated RSAS campaigns, movement is very slow during the high-intensity period of an attacker's assault on prepared defenses. Rapid movement *follows* breakthroughs, and

[4]The RSAS also allows the FMR to be calculated from force ratios. The attrition-based procedure is intended to better integrate the effects of tactical aircraft, though it does not explicitly account for the focusing of those effects or of ground combat in massed sectors, an effort that is still ongoing.

is correlated with periods of relatively low loss rates when the defender is withdrawing and regrouping.

The FLOT movement rate is also constrained by a maximum velocity in each type of terrain. The result is that the force ratio and type engagement determine the defender's loss rate and the exchange rate, and through these the FLOT movement rate. The DLR is the fraction of the defending force lost in this assessment cycle. For example, the defender may have lost 10 percent of its force. If the defending strength was 240 points, then the defender lost 24 points. The ER is the ratio of attacking strength lost for every point of defending strength lost. If the ER was 2.0, then the attacker lost 2.0 times 24 points, or 48 strength points. The attacker's loss rate can be determined by dividing what was lost by the starting strength (for an attacker with initially 600 points, this would equal 8 percent).

The loss rates that occur in the RSAS are gross losses. A separate repair rate is then applied to reflect losses that are recoverable. This repair rate is a function of the ability of each side to repair its losses and also of the tactical situation (e.g., a defender being pushed back rapidly cannot recover much of its damaged equipment for repair). Both CAMPAIGN-MT and CAMPAIGN-ALT have an instantaneous repair function that reflects local (divisional) repair efforts. CAMPAIGN-MT also has a theater-level repair function with a time delay associated with such repairs.

STEP 13: DETERMINE SITUATIONAL STRENGTH POINTS LOST BY EACH SIDE

Multiply the loss rates of row 12 by the total of row 9. This will be used in the casualty distribution calculations. In our example, 8 percent of 532 is 42.5 situational strength points.

6. CASUALTY DISTRIBUTION

After the combat results have been assessed, the losses to each side are distributed among the assets of each force. Since the fraction of the total strength points lost to a force is known, the SFS methodology ensures that the losses in each category of weapon sum to the total force strength lost in this battle. The situational category strengths are used to determine how the losses are proportioned between different types of weapon systems. The final force strength before combat is used to normalize these values so that the total force strength lost equals the strength lost by the force in this assessment cycle.

Before explaining the details of the steps, we present a brief description of the concept behind the process. As mentioned in the introduction, one of the problems with traditional force-on-force models that employ static force scores is that the loss rates to each category of weapon are the same as the overall force loss rate. For example, if the force takes 5 percent losses, then each category of weapon will take 5 percent losses. However, this does not match either the historical evidence or the results from higher-resolution combat models.

From historical studies and a wide range of higher-resolution games and simulations, it is clear that the loss rates tend to be higher for armor assets and lower for artillery assets. For example, the loss rates of armor may have been 18 percent of the engaged armor, while artillery loss rates may have been 2 percent of the artillery assets engaged, and infantry loss rates were about 5 percent. In order to place this type of information in a form useful for purposes of extrapolation, we estimated a category loss multiplier for each category of weapon. The current multipliers are merely first-cut subjective judgments, but they are much better than the default assumption that the multipliers are all unity.

In a given calibration case, tanks may make up 40 percent of the initial force strength, but provide 50 percent of the force strength *lost* in this battle. As a result, tank losses contribute 1.25 times the fraction of the force strength tanks initially contributed in a given type of battle. This ratio of 1.25 is then used to determine the relative magnitude of the losses in a specific extrapolation case. For example, if armor made up only 10 percent of the force strength, then only 12.5 percent of the losses would be contributed by armor. Conversely, if armor made up 64 percent of the force strength, then armor would make up 80 percent of the strength lost.

Since there is no way to guarantee all of the resulting relative loss rates will sum to 100 percent, all of the relative loss rates for each category of weapon are then normalized.

Therefore, if the force was assessed to have lost 5 percent, then the sum of the strength points lost will add to 5 percent of the initial force strength after normalization.

This casualty distribution method tends to drive the relative attrition between sides and between categories of weapons on a side to move in the right direction. For example, if one side is more effective due to situational and shortage multipliers, it will tend to suffer less overall attrition than the other side. If a given category of weapon is more effective, then it will suffer less attrition. Say that the defender has little anti-armor capability. Therefore, the attacker's armor is given a benefit in effectiveness before attrition is assessed. The defender suffers higher attrition and the attacker suffers lower attrition due to the lack of defending anti-armor. (If a breakthrough is assessed to have occurred, additional attrition and lack of recovering damaged assets also are assessed against the defender.) In addition, the same shortage multiplier is divided into the attacking armor strength during casualty distribution. As a result, armor suffers relatively less attrition than the other categories of weapons than would have been the case if the defender had better anti-armor capabilities.

STEP 14: START WITH THE FINAL CATEGORY STRENGTH POINTS

The final category strength points are the starting point for the casualty distribution calculations and are found in row 9 of Table 2.1 in our example. These strengths are used to determine the fraction of strength contributed by each category of weapon.

STEP 15: DETERMINE THE CATEGORY LOSS MULTIPLIER

Casualty distribution is important because different types of weapons are destroyed at different rates depending upon the situation and the opponent's mix of capabilities. For example, in our calibration case, tanks may make up 40 percent of the initial force strength but provide 50 percent of the force strength *lost* in this battle. As a result, tank losses contribute 1.25 times the fraction of the force strength that tanks initially contributed. A look-up table is used to determine the casualty distribution for each type of engagement. This look-up table can be created from either historical data or higher-resolution combat models. Our initial values are shown in Table 6.1.[1]

In Table 6.1, assault-type battles are those with different degrees of defender preparation (hasty, deliberate, prepared, and fortified). We also differentiate between battles where the primary assault weapon is armor as opposed to infantry. This is more a question of doctrine than of force mix, and thus needs to be established based upon national style and

[1]Bruce Bennett developed this table of proposed values.

Table 6.1

Category Loss Multipliers

Primary Assault Weapon	Type of Battle	Attacker			Defender		
		Armor	Infty	Arty[a]	Armor	Infty	Arty[a]
Armor	Assault	1.5	1.0	0.7 * CB	1.2	1.0	0.7 * CB
Infantry	Assault	0.5	2.0	0.7 * CB	0.5	2.0	0.7 * CB
Armor	Meeting	1.5	1.0	0.7 * CB	1.5	1.0	0.7 * CB
Infantry	Meeting	0.5	2.0	0.7 * CB	0.5	2.0	0.7 * CB
Armor	Stalemate	1.5	1.0	2.0 * CB	1.5	1.0	2.0 * CB
Infantry	Stalemate	0.5	1.0	2.0 * CB	0.5	1.0	2.0 * CB
—	Withdrawal	2.0	1.0	0.2 * CB	1.2	1.0	0.4 * CB + 0.4
—	Breakthrough	2.0	1.0	0.2 * CB	1.2	1.0	0.4 * CB + 0.4
—	Delay	1.5	1.0	0.7 * CB	1.5	1.0	0.5 * CB

[a]"CB" is the opponent's counterbattery capability as discussed in Section 4.

not just the specific forces involved. For example, in Korea, initial assaults and defenses will be dominated by infantry, with armor playing at most a fire support and exploitation role; armor can therefore be expected to suffer relatively low losses, and infantry can be expected to suffer relatively high loss rates. (In this and other areas, the parameters and even some of the basic SFS logic needs to be reviewed when applied to different theaters to make sure that the SFS concepts adequately reflect the doctrine and force structures of each side.)

We also allocate losses to artillery as a function of the counterbattery fire capability of the opposing side, as discussed in Section 4. Note that if the artillery losses are higher, the losses to the other categories of weapons will be higher during this assessment cycle, since the artillery focusing on counterbattery will not be focusing on hitting maneuver units. However, as one side's artillery becomes severely degraded through counterbattery fire, the effectiveness of that side's maneuver elements will be reduced in subsequent combat assessment cycles.

Finally, note that there is an additional loss assessed against artillery assets in the breakthrough and withdrawal cases.

STEP 16: APPLY THE SHORTAGE FACTORS

Row 8 is duplicated in Row 16. The shortage multipliers are included in casualty distribution because shortages affect the pattern of casualties caused. For example, if an opponent is short anti-armor weapons, his ability to destroy enemy armor is impaired, and he will damage relatively less of it, as described in the earlier example.

STEP 17: CALCULATE THE RELATIVE LOSS RATE

This calculation *multiplies* the category loss rates times the final category scores, and *divides* this product by the shortage multipliers. The resulting values reflect the relative loss rates that each weapon category should be assigned. A shortage multiplier less than one (meaning that category of weapon is less effective) will increase the relative category strength to be lost during this assessment cycle.

STEP 18: CALCULATE THE NORMALIZED CATEGORY STRENGTH LOST

Row 17 is multiplied by row 13, and divided by the total of row 17. The result is the *normalized* category strength lost for each category of weapon. Note that the strength lost by each category sums to the total final strength lost (in this case, 42.5 strength points).

STEP 19: FRACTIONAL LOSS

Row 18 is divided by row 14. The result is the fraction of *final* strength lost in each weapon category. This step is included primarily because the RSAS prefers to calculate the fraction of assets lost in each category of weapon, rather than first calculating the number of assets lost by category of weapon.

STEP 20: CALCULATE NUMBER OF ASSETS LOST BY EACH WEAPON CATEGORY

Row 19 is multiplied by row 1 in Table 2.1. The result is the number of assets lost by each category of weapon. This completes the description of the SFS methodology, except for some optional features described in the following section. For example, once the assets lost in each category of weapon have been determined, one can then produce the optional KV-scoreboard outputs, or use a calibration KV scoreboard to produce a KV-scoreboard output as described in the next section. Note that if the same number of each type of assets is used in the extrapolation case, the number of assets lost in each category of weapon will exactly match the calibration case. If the input number of assets in the extrapolation case do not match the calibration case, then the SFS methodology will act as an extrapolation methodology similar to other existing KV-scoreboard methodologies. This is a significant feature for a force-on-force methodology, since previously only killer-victim scoreboard methodologies could make that claim.

7. OPTIONAL FEATURES

One can employ five optional features when using the SFS methodology:

- Apply new measures of effectiveness defined by situational scores.
- Produce KV-scoreboard output from SFS methodology data, and calibrate SFS casualty distribution to KV scoreboards.
- Represent systems with both high lethality and high vulnerability.
- Allow for conservation of scarce assets at reduced effectiveness.
- Distinguish different generations of armor and anti-armor assets.

NEW MEASURES OF EFFECTIVENESS

Standard force scores used in most aggregate combat models compare relative force strengths on each side. These standard force scores are situation-independent, and therefore do not reflect the comparative advantages or disadvantages faced by each side in the current situation. The situational force scores described in this paper reflect the strength of the forces on each side in a specific situation. The difference between these two force-scoring mechanisms can be used to create a new measure of effectiveness (MOE).

The difference between the standard attacker-to-defender force ratio over time and the situational force ratio demonstrates the degree of advantage one side has over the other in the current situation (see Fig. 7.1). In this example, the theaterwide force ratio is used, but local force ratios work on the same basis. Note that at the start of the conflict, the situational force ratio is less than the standard force ratio. Due to the defender's preparations and choices of terrain for defensive positions, the attacking force has less of an advantage than is shown by the standard force ratio. However, as the war proceeds, local breakthroughs occur, and the defender may be forced to fight from less-advantageous positions.[1] As a result, the situational force ratio may shift from benefiting the defender to benefitting the attacker. By the end of this example, the attacking force has more of an

[1]An alternative approach is to display both unadjusted and SFS force strengths and ratios as a function of time *without* considering the results of combat. Such quasi-dynamic analysis methods can be very useful in evaluating force capabilities for a range of contingencies that stress early use of warning, strategic mobility, and the suitability of forces for the types of conflict into which they are likely to deploy. One can then supplement the quasi-dynamic analyses with war-gaming and simulation of selected cases (e g., using the RSAS).

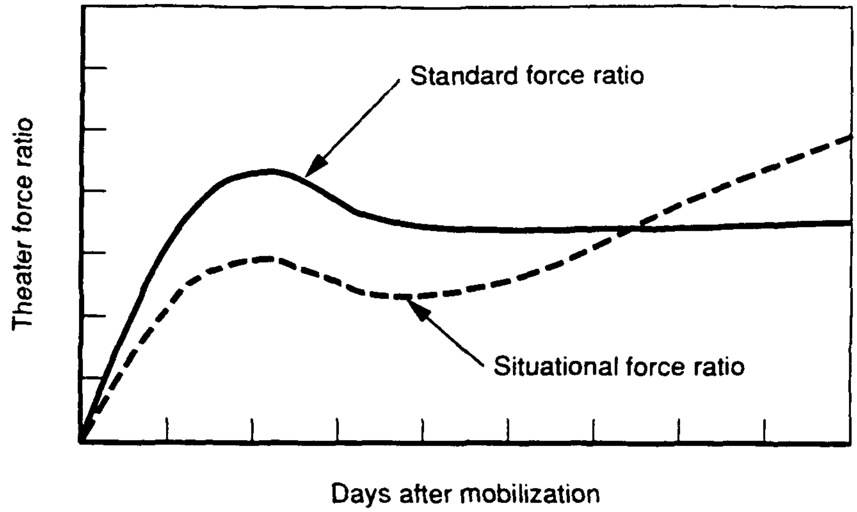

Fig. 7.1—Sample of New Situational Force Ratio MOE

advantage than might be observed from the standard force ratio. This is because the attacker has the advantage in most of the combat situations occurring in the theater at that time.

Note that in a different example, if the attacker was not successful in creating breakthroughs, then the situational force ratio would tend to remain below the standard force ratio throughout the conflict. Also note that if the defender switched to a counterattack, then the force ratio may temporarily shift adversely against that side until the counterattack succeeds.

If one is attempting to examine the effects of conventional arms control limitations by specific types of weapon systems, this situational force ratio comparison would be very useful. Otherwise, an arms control option that may seem beneficial in some combat situations may actually be less beneficial when examined over many combat situations.

KV-SCOREBOARD OUTPUT

There are two unique features of the SFS methodology. The first is that there is sufficient data available to prepare an output similar to those produced by the KV-scoreboard methodologies. The second feature is that the SFS methodology may be calibrated to KV scoreboards using values calculated from KV-scoreboard methodologies. We will demonstrate in this section that the main parameters in the SFS methodology can be explicitly calibrated to a KV-scoreboard methodology and produce exactly the same results as the KV-scoreboard methodology in the calibration cases. When extrapolating away from the calibration cases, the SFS methodology will probably extrapolate differently from the KV-scoreboard methodology (unless, importantly, a repro model is used to represent the more-detailed model's attrition process), but may work sufficiently well for the analysis at hand. More importantly, the SFS methodology may be used for analysis to a level of detail equivalent to KV scoreboards even in the absence of sufficient calibration cases. KV scoreboards cannot operate in the absence of calibration boards, but the SFS methodology can. Of course, the accuracy of the SFS methodology is only as good as its input assumptions and parameters. It seems, however, that even the initial set of assumptions and parameters are much better than the default assumptions implicitly included in traditional force-on-force aggregate models. Nonetheless, the best use of SFS is probably in conjunction with selected KV-scoreboard methodology boards to increase the confidence of SFS results. Each of the preceding points will be discussed in more detail in this subsection.

Sufficient Data to Prepare KV-Scoreboard Type of Output

Another advantage to distinguishing between the effectiveness of different categories of weapons is that the SFS methodology provides sufficient information to produce KV-scoreboard type outputs. It is true that such a distribution of losses will require some assumptions, but these assumptions will be at least consistent with the assumptions used to calculate the situational force ratio in the first place. As we will show below, the closer the SFS methodology is to the calibration cases, the better these approximations will be. The farther we are from the calibration cases, or if there are no calibration cases available, then we should be very aware of the high degree of uncertainty regarding KV-scoreboard outputs from the SFS methodology.

The following numerical example will be used to demonstrate the principles behind KV-scoreboard type outputs. Let us assume we want to know how effective artillery is against armor in a particular situation. First, create a calibration table with the rows representing the shooters and the columns representing the targets. This table will include the number of tanks killed by artillery in the calibration case. Second, create a similar table that uses the same rows and columns, but the table entries are not yet filled in. Third, extrapolate from the calibration table to fill in the new table entries. This extrapolation methodology is based on using the calibration entry and modifying it by a factor that accounts for the numbers of artillery shooters and tank targets in the calibration case to the number of artillery shooters and tank targets in the new case.

Part of the problem with KV-scoreboard methodologies is that if a certain weapon system does not kill another type of weapon system in the calibration case, it will never kill that kind of weapon system in the extrapolated cases. Therefore, if there were a force consisting of artillery against an infantry and armor force, and the calibration data did not include the fact that armor and infantry can kill artillery, then the pure artillery force would unrealistically defeat the armor and infantry force.

To preclude this type of problem, the SFS methodology focuses on which types of systems *could* kill other types of systems in a given situation. The implication is not that one type of weapon system did kill other systems in a given battle, but that one type of weapon system could have killed another type of weapon system. This information can be displayed in a KV-scoreboard type of array.

The losses of each type of weapon system are obtained from the last row of the casualty distribution section (Table 2.3, row 20). The types of weapon systems that could have killed these damaged systems are obtained from the mapping of weapon strength into killing potential or ability (Table 4.2). Therefore, one can distribute to each shooting system a fraction of the kills. This fraction is based on the proportion that each system *could have* killed in this type of situation.

In Table 7.1, the tanks lost by the attacker are distributed among the defending assets according to their killing potential and initial strength in the battle. The defender category strength is multiplied by the defender's anti-armor potential to obtain a raw anti-armor strength. This value is normalized and then multiplied by the number of attacking tanks killed. The result is the number of attacking tanks that could have been killed by each category of defending weapon. All of the losses by category of weapon can be distributed in this manner, thereby creating a full KV scoreboard.

Calibrating SFS Parameters to KV-Scoreboard Methodologies

There are five types of parameters in the SFS methodology that drive the attrition results:

- Situational multipliers
- Shortage multipliers
- Loss rates for the attacker and defender
- Loss ratio multipliers by category of weapon
- Allocation of killing potential against each type of target

Table 7.1

KV-Scoreboard Type of Output from SFS Methodology

Defender Categories of Weapons	Defender Assets This Battle	Defender Anti-Armor	Defender Raw Anti-Strength	Norm Anti-Strength	Attacker Tanks Lost by Category
Tank, IFV, ARV	300	0.73	220	0.44	14.9
APC	50	0.30	15	0.03	1.0
LR AT	50	1.00	50	0.10	3.4
SR AT	100	0.50	50	0.10	3.4
Infantry	1500	0.05	75	0.15	5.1
Arty	150	0.60	90	0.18	6.1
Total			500	1.0	33.9

We will describe how to calibrate each of these types of SFS parameters to a KV-scoreboard methodology. For our example, we will calibrate SFS parameters to the ATCAL KV-scoreboard methodology.

Calibrating situational multipliers. For each calibration case, there is one situational multiplier for each category of weapon for each side. Let us assume that there are N categories of assets on the attacking side, and M category of assets on the defending side. Let XS and YS be the starting number of defending and attacking assets on each side, and XL and YL be the number of assets on each side lost in this case.

In the ATCAL methodology, the *combat worth* of a category of weapon is defined to be the number of assets of that type times the *importance* of that type of asset. Although the combat worth is not used for adjudication purposes in ATCAL, it is used in the command and control process to make force-related decisions. The importance of an asset is calculated dynamically based upon simultaneous nonlinear equations that focus on the lethality of a type of weapon relative to all other types of weapons on each side. We will use the importance as defined by ATCAL in a calibration case to calibrate the SFS situational multipliers. The situational multipliers account for the terrain and type of battle effects, but not the shortage effects. As a result, we are assuming that the calibration case did not have shortages in combined arms. See the next part for when shortages are included in the calibration case.

For the ith category of weapon, let us equate the combat worth as defined in ATCAL with the category force score defined in SFS, or

$$XS(i) * Imp(i) = XS(i) * Val(i) * Sit(i),$$

where Imp(XS) is the importance of this asset type in this calibration case, Val(i) is the value of the asset as defined by the standard force scoring mechanism, and Sit(i) is the situational multiplier we are trying to determine. This equation can easily be solved for the situational multiplier, since the only unknown factor is Sit(i).

$$\text{Sit}(i) = \text{Imp}(i) / \text{Val}(i).$$

This equation can be determined for each category of weapon. Using this definition, the situational force multiplier may be considered the factor that modifies the standard force score to match the importance of the weapon in the situation as defined by the ATCAL methodology.

Calibrating shortage multipliers. The SFS shortage multipliers and effects may be defined in a manner similar to the situational multipliers for type of terrain and type of battle. Let us assume that there is a calibration case with no shortages, and that the situational multipliers have been determined. Now run the same case, except that a shortage exists. Note that in this calibration case, ATCAL will define a different importance for each category of weapon. Therefore, the following equation applies:

$$\text{XS}(i) * \text{Imp}(i) = \text{XS}(i) * \text{Val}(i) * \text{Sit}(i) * \text{Short}(i),$$

where the only unknown in this equation is the shortage multiplier. Note that to calibrate the shortage multipliers, one must first have a calibration case without shortages. Fortunately, most calibration cases include no shortages on each side. This has also been part of the problem of KV-scoreboard methodologies in that one rarely runs cases where there are shortages of a combat arm, which is why KV scoreboards have had difficulty extrapolating to cases where such shortages exist.

Calibrating loss rates for the attacker and defender. To calibrate the loss rate parameters, we must first determine the force ratio. In ATCAL, the force ratio is the ratio of the combat worth of the attacker (summed over all asset types) divided by the combat worth of the defender. This force ratio is not used in ATCAL for attrition purposes, but for decision purposes. The force ratio in ATCAL may be equated to the force ratio in the SFS methodology.

$$\begin{aligned} &\text{SUM}\ \{\ \text{YS}(j) * \text{Imp}(j)\ \} / \text{SUM}\ \{\ \text{XS}(i) * \text{Imp}(i)\ \} = \\ &\qquad \text{SUM}\ \{\ \text{YS}(j) * \text{Val}(j) * \text{Sit}(j)\ \} / \text{SUM}\ \{\ \text{XS}(i) * \text{Val}(i) * \text{Sit}(i)\ \}, \end{aligned}$$

where SUM denotes the sum over all categories of weapons on a side. Given that the force ratios are the same, we can now equate the defender and attacker loss rates. In our example, we will only display the defender loss rate. The loss rate of the defending force as measured in combat worth is:

SUM { XL(i) * Imp(i) } / SUM { XS(i) * Imp(i) }.

This single value is used to calibrate the attrition curves for each type of battle, as described in Section 3. In a similar manner, one can determine the attacker loss rate. From the force ratio and the attacker loss rate, one can determine the exchange ratio, which is what the RSAS uses for determining the attacker loss rate.

Not all models define the attacker and defender loss rates as a function of the force ratio. From our early calculations, it appears that the ATCAL and CADEM methodologies define the defender loss rate as a nearly linear function of the attacker force strength, and the attacker loss rate as a nearly linear function of the defender force strength. This formulation is similar to the Lanchester linear law. As a result, one must be careful when calibrating SFS parameters to another model that the form of the attrition curves match the type of model being calibrated to. Otherwise, comparisons of calibrated and extrapolated output would be meaningless.

Calibrating loss ratio multipliers by category of weapon. The loss ratio multipliers are also calculated using the concept of combat worth. First, we calculate the contribution of each category of weapon to the overall force strength before the battle, or

XS(i) * Imp(i) / SUM { XS(i) * Imp(i) }.

Second, we calculate the combat worth of the losses of each category of weapon to the overall combat worth lost in this battle.

XL(i) * Imp(i) / SUM { XL(i) * Imp(i) }.

The unknown loss ratio multiplier Mult(i) can then be calculated from these two known values:

$$\text{Mult}(i) = \frac{XL(i) * \text{Im}\,p(i) / \{XS(i) * \text{Im}\,p(i)\}.}{\text{SUM}\{XL(i) * \text{Im}\,p(i)\} / \text{SUM}\{XS(i) * \text{Im}\,p(i)\}}.$$

If shortage effects are present in the calibration case, then a similar calculation is required to determine the effects of the shortage on the casualty loss multiplier. In this case, the multiplier for the case with shortage is equal to the multiplier of the case without the shortage times the shortage casualty multiplier. Note that in the absence of a calibration case, the SFS methodology assumes that the shortage casualty multiplier is one over the shortage effectiveness multiplier so that the effects of the shortage modify the losses by category in the right direction.

Calibrating the allocation of killing potential against each type of target. Since this is an optional feature in the SFS methodology, this calibration step is presented last. To produce KV-scoreboard outputs from SFS data, collect the following information from the KV scoreboard. For a single category of target, calculate the fraction of those targets killed by each category of weapon. For the jth target, the ith fraction is:

$$\text{Fraction } (i, j) = \frac{XL(i, j)}{XL(i)},$$

where XL(i,j) is the number of assets of the ith category killed by the jth shooter. Note that this will require the same number of data elements required in the KV scoreboard in the first place. On the other hand, we may prefer to use only broad categories of targets, as shown in Table 4.2. If we want an exact match with the KV scoreboard, then we should collect this fraction for every combination of shooter and target, as provided by the KV scoreboard.

Since the earlier SFS parameters were calibrated to a KV-scoreboard methodology for a specific type of battle, then for that type of battle, all of the SFS outputs will match the KV-scoreboard outputs for every element in the KV scoreboard at the point of calibration. That is, given the same number of starting assets and total losses by target category of weapon, the SFS methodology will produce the same loss distribution as the KV scoreboard.

Comparing SFS and KV-Scoreboard Extrapolation Methods

When extrapolating away from the calibration cases, the SFS methodology will probably extrapolate differently from the KV-scoreboard methodology but may work sufficiently well for the analysis at hand. The following numerical example is used to show how the SFS methodology can be used to extrapolate from a KV-scoreboard calibration case.

The first step is to increase (or decrease) the number of kills by each shooter by multiplying by the ratio of assets for each shooter in this case versus the calibration case. The second step is to normalize the losses (the columns of a KV scoreboard) to the number of assets lost in this battle according to the SFS methodology (see Table 7.2).

Table 7.2

Scoreboard Type of Output from Calibration Data

Defender Categories of Weapons	Defender Assets This Battle	Defender Assets Cal. Battle	Scoreboard Column Multiplier	Scoreboard Att. Tank Losses	Raw Att. Tanks Lost by Category
Tank, IFV, ARV	300	360	0.83	24	19.92
APCs	50	55	0.91	2	1.82
LR AT	50	75	0.67	12	8.00
SR AT	100	200	0.50	8	4.00
Infantry	1500	950	1.58	2	3.16
Arty	150	175	0.86	6	5.16
Total				54	42.06

Defender Categories of Weapons	Raw Att. Tanks Lost by Category	$\frac{33.90}{42.06}$	Final Att. Tanks Lost by Category
Tank, IFV, ARV	19.92	0.806	16.06
APCs	1.82	0.806	1.47
LR AT	8.00	0.806	6.45
SR AT	4.00	0.806	3.22
Infantry	3.16	0.806	2.55
Arty	5.16	0.806	4.15
Total	42.06		33.90

To demonstrate this extrapolation capability, we calibrated both the CADEM methodology and the SFS parameters to the same four-weapon (two on each side) KV-scoreboard. The attrition curve (the Lanchester linear law described above) was calculated strictly from two CADEM extrapolation cases so that the attrition curves as a function of the force strength could be defined. We then varied the initial force strength on each side by category of weapon from 75 percent to 125 percent of the initial force strength. The end result was that the SFS-output KV-scoreboard elements were within 10 percent of the CADEM-output KV-scoreboard elements. Although this simple experiment is not sufficient to conclusively demonstrate the ability of SFS to extrapolate as well as CADEM across a wide variety of cases, it did accomplish the necessary condition of demonstrating that it does extrapolate well in the cases examined so far. Numerical experiments with larger numbers of weapons on each side and more varied force mixes are currently being performed.

It is true that all of the SFS parameters are scalar values and that one set of these scalar values will not by themselves take into account any synergistic effects between categories of weapons. However, the following factors all contribute to cause the net effects of the SFS multipliers on the distribution of losses to be nonlinear: The scalar values differentially weight the categories of weapons by type of combat situation; the shortage effects are differentiated by category of weapon; the attrition curves are nonlinear; the loss ratio multipliers are differentiated by category of weapon; and the fact that one renormalizes the losses across all categories of weapons to match the loss rate.

This fact cannot be stated too strongly, since it has been argued that scalar multipliers can never account for synergistic effects between assets. If one were using scalars only to multiply the force strength as a whole, this would be a true statement. However, since the scalar multipliers are applied differentially to each category of weapon, then the net effect is that many of the synergistic effects between categories of weapons are being explicitly accounted for in the SFS methodology.

At any calibration point, the SFS methodology will replicate exactly KV-scoreboard outputs. Away from the calibration points, the SFS methodology will extrapolate differently than will a KV-scoreboard extrapolation methodology. In early experiments, SFS appears to extrapolate sufficiently well to match CADEM extrapolations across the small set of cases already examined. More importantly, the SFS methodology is the first score-based methodology that can be calibrated to a higher-resolution KV-scoreboard methodology.

The Best of Both Worlds

As shown above, the SFS methodology can produce exactly the same results as a KV-scoreboard methodology given they are at a common calibration point. SFS will extrapolate differently from a KV-scoreboard methodology, and if we assume that both the high-resolution model and the extrapolation KV-scoreboard methodology adequately reflect all of the important combined arms factors, then we should rely more on the KV-scoreboard results than on the SFS results. However, there are two situations where SFS results may be considered more credible than KV-scoreboard results.

The first case is where there is some reason to believe that either the high-resolution model or the KV-scoreboard methodology is not accounting for some important factors, such as level of training, shortage effects, or extreme force mixes.

The second case is where high-resolution model runs for a particular area of interest could not be obtained within the time available for analysis. Under these circumstances, the SFS methodology is the only methodology available to even begin to address force mix and combined arms issues in a given theater of operations. KV-scoreboard methodologies cannot operate in the absence of KV scoreboards, but the SFS methodology can. In the absence of more solid data, judgment rules.

The good news is that in many cases, we are not faced with a completely either/or situation. There may be a few high-resolution model runs available for a given theater of operations, but not a sufficient number to adequately cover the types of combat situations likely to be encountered. However, the SFS methodology can be used to address combat outcomes in the whole theater of operations given that it has been calibrated exactly to the calibration cases (using a KV-scoreboard methodology as described above) and that reasonable estimates can be created for the off-calibration cases. In many respects, the SFS methodology bridges the gap between the force-on-force analysis tools and the weapon-on-weapon analysis tools.

LETHALITY AND VULNERABILITY

The RSAS combat assessment methodology presented in Section 5 does not consist of standard Lanchester-type calculations, nor is it intended to. Combat adjudication in the RSAS is based upon historical data on the sizes of forces facing each other in specific types of battles. As with most aggregate force-on-force combat adjudications, the assumption is that the lethality of the weapons and their survivability are roughly proportional. Weapons with high combat effectiveness have both a good lethality and a high survivability factor. This assumption is valid because the definition of effectiveness usually includes a weighted value of lethality and survivability, as in the WEI/WUV methodology.

However, there are some cases in which the weapon's lethality is much greater than its survivability. A good example of this is attack helicopters: They don't tend to last very long in combat, but they do a lot of damage while in the fight. That is one reason why the RSAS assesses combat with attack helicopters separately from the rest of the aggregate ground combat adjudication.

There is another alternative to representing selected assets that have high lethality and low survivability. In this alternative, the lethality of the weapon system is used as the basis of the asset's effectiveness. At the time of casualty distribution, a separate factor is applied to the category loss multiplier to account for the lower survivability. If the calibration data is correct, the fraction of the losses contributed by this asset will be accurate. However, if this is a new weapon system with a similar gun and reduced armor (like a mobile protected gun), then one may require an additional multiplier to account for reduced survivability.

For example, if a 105 mm gun were to be mounted on a chassis that had armor like an M113, this weapon would have a lethality similar to an M60A3 (subject to platform stability, range-finding equipment, rate of fire, etc.) but a survivability similar to an M113 (or less, since M113s do not tend to be high-priority targets because they can't kill enemy tanks). If this type of weapon system is not represented in the calibration data for force effectiveness by situation and casualty distribution, existing data points could be used to "build" the combat results appropriate for this new type of weapon. The lethality data would be used for the effectiveness, while the casualty data would be modified by a multiplier to account for the reduced survivability.

It should be noted that although the SFS methodology can account for broad differences between the lethality and survivability of a given weapon or category of weapons, it is not a good tool to *identify* differences between lethality and survivability. We should probably use physical experiments, more detailed combat models, or at least a weapon-on-weapon combat methodology to identify these differences.

CONSERVATION OF SCARCE ASSETS

In some combat situations, one side may be near a shortage condition. Rather than use scarce assets unwisely, the commander may choose to conserve them. This will have two effects: First, the assets will take fewer casualties; and second, the overall force strength will be less effective, because the scarce assets are not likely to always be available when they are needed.

To implement these effects in the SFS methodology, two steps are required. First, the effectiveness multiplier for that category of weapon is increased by a specified amount (for example, 30 percent). This will reduce the losses of the scarce assets during the casualty distribution process. Second, a force multiplier is applied that reduces the overall force effectiveness by the equivalent of *twice* the increase caused by the first step. This will reduce the overall force effectiveness, which represents the fact that these assets are less available when they are being conserved.

Conserving assets requires a conscious trade-off of benefits. If the scarce assets are not conserved, the force may be faced with a shortage that creates an extreme effect in the SFS combat assessment adjudication. If the scarce assets are conserved, then the overall force is less effective. This is a realistic trade-off that was faced often by the Germans in World War II, especially when their armor assets were scarce.

ARMOR AND ANTI-ARMOR GENERATIONS

One of the major concerns in the development of armor and anti-armor is that some types of anti-armor assets are currently obsolete against some of the latest armor types. For example, double-warhead antitank weapons are now required to defeat reactive armor. Certain types of earlier armor were effective against the lighter hand-held anti-armor weapons. Since there is a wide discrepancy between different generations of armor and anti-armor weapons, these considerations will need to be taken into account, especially in a conventional arms control environment.

One way to handle this situation is to discount certain types of anti-armor weapons against certain types of armor assets (see Table 7.3). One way to interpret this table is to consider the fact that even older-generation anti-armor weapons will be able to destroy newer generation tanks in some situations. The number of situations in which this can occur decreases significantly when one is looking at first-generation anti-armor against third-generation armor. The modest increase in effectiveness of newer-generation anti-armor against older-generation armor accounts for the fact that under these circumstances, a hit is more likely to be a kill.

Table 7.3

Discount Factors for Generations of Armor and Anti-Armor

	Armor Generation		
Anti-Armor Generation	Type I (Armor)	Type II (Cobham)	Type III (Reactive)
Type I (Shaped charge)	1.0	0.7	0.2
Type II (Large shaped charge)	1.1	1.0	0.5
Type III (Double warhead or kinetic energy round)	1.2	1.1	1.0

These factors are applied to a force based upon the numbers of shooters and targets on each side. For example, an armor force of Type III tanks attacks a force that contains 100 Type I, 50 Type II, and 50 Type III anti-armor assets. The number of effective anti-armor assets is 95 (0.2 x 100, plus 0.5 x 50, plus 1.0 x 50), rather than 200 (100 plus 50 plus 50). Note that the anti-armor strength is greatly reduced when one includes the different generations of armor and anti-armor. This reduction also makes it more likely that the defender will not have a sufficient density of anti-armor assets to fight the next battle. (Both the losses of anti-armor assets and the consumption of anti-armor missiles should be based upon the 200 anti-armor assets actually engaged, rather than the 95 "effective" assets. This is because in order to achieve a force that fought effectively as 95 Type III anti-armor assets, 200 lower quality anti-armor assets were required.)

8. CONCLUSIONS

The SFS methodology presents an advance in the state of the art of aggregate combat models by accounting for combined arms effects frequently absent in models that employ static force scores. In addition, the SFS methodology will replicate the casualty distribution results of the calibration KV scoreboard, given the same force mix, force size, type of battle, and type of terrain. This latter feature, usually associated with killer-victim scoreboard methodologies, is a significant advance over previous force-on-force attrition methodologies.

The known limitations of the SFS methodology are as follows: The SFS methodology will *account* for many variations in different weapon systems, but it is not designed to *identify* these differences, such as a broad difference in the lethality and the survivability of a weapon system. The strength in the SFS methodology is that it will better account for how a given weapon system will fare as part of a whole force in the realm of combined arms actions, rather than focus on identifying specific weapon system parameters. Similarly, the SFS methodology is not appropriate for use in models that include line-of-sight calculations for combat assessment.

As with most combat models, the SFS methodology is only as good as its data. Although sample data have been provided in each case, a more-detailed examination of the input data is required. To ensure the best estimates for the data, we recommend that a Delphi process (or something even more structured, as in the Subjective Transfer Function method) be initiated to survey knowledgeable personnel and prepare a revised set of numbers. Spreadsheet tools have been developed to assist in the data definition process (described in Appendix C). Although the data requirements for the SFS methodology may be substantial, they are much less demanding than the comparable weapon-on-weapon attrition methodologies. If, however, weapon-on-weapon data are available, the SFS parameters may be calibrated exactly to reproduce the calibration cases.

Some of the effects of attack helicopters and fixed-wing aircraft on the close battle have been included in the SFS methodology. However, there are a number of other qualitative, less direct attrition effects that need to be researched in more detail before being included in this methodology. There are many other combat assets that could be included in this methodology, such as lasers, electromagnetic launchers, or non-line-of-sight close-combat assets.[1] If one has a feel for how these assets could be used in the close battle and how they would influence the battle as a function of the situation, then they could be included in the methodology. However, any such representation would depend upon the assumptions employed, as is true for other current combat assessment methodologies.

There has been some question as to whether there would be sufficient data to adequately calibrate the SFS parameters. At the moment, aggregate force-on-force combat models tend to ignore many of the basic benefits of the different combat arms in different situations. Therefore, it would be better to employ a methodology with some uncertainty than to continue to employ the current methodologies that are known to be biased. Static force scores tend to be biased in favor of armor or artillery (depending upon the scoring mechanism employed) and biased against infantry and their assets. Ignoring the problem will not cause it to go away. Instead, this will continue to exacerbate a problem frequently encountered in defense analysis and procurement. It is time to move the representation of explicit combined arms effects out of the "too hard to do" box, and into the realm of the "doable." As high-resolution modeling and war-gaming are now becoming increasingly sophisticated and economical, it will also be feasible to draw on them for insights and, in some cases, calibration points.

[1]The SFS methodology has been designed to represent the close battle, rather than the deep or rear battles. Therefore, missile systems (such as ATACMs) are not included in this methodology unless they are to function similar to artillery in the close battle.

Appendix A
A LESS-DETAILED VERSION OF SFS

The full SFS methodology is more detailed than may be necessary to fulfill the requirements for many applications. For example, a quick-response study may wish to account for the more basic situational strengths as a function of terrain and type of battle, rather than the details of force mix or casualty distribution.

Therefore, we have created a less-detailed version of the SFS methodology that accounts for the effects of the combat situation as a function of the types of units engaged, with an option to account for disproportionate casualty distribution and platform shortages. In addition, the new measures of effectiveness described above (the situational force ratio) may be applied to this less-detailed methodology.

The steps of the reduced SFS methodology are shown in Table A.1 and described in detail below.

Table A.1

Sample Precombat Calculations in the Reduced SFS Methodology

	Types of Units in Force			
Calculation Step	Armor	Mechanized	Infantry	Total
Basic type unit strengths in EEDs (row 1 multiplied by row 2)	1.0	0.8	0.3	2.1
Situational unit multiplier (obtained from look-up table; varies by combat situation)	1.1	1.5	2.0	
Raw situational unit strength in SEDs (row 1 multiplied by row 2)	1.1	1.2	0.6	2.9
Unit loss and shortage force modifier (optional)				1.0
Final situational force strength in SEDs (row 3 multiplied by row 4)				2.9

STEP 1: BASIC TYPE UNIT STRENGTHS IN EEDS

Each unit engaged in this battle is divided into type of unit, with the effective equivalent division (EED) strengths of similar types of units added together. Since the effectiveness multipliers apply to each unit, these must already be applied before summing together the strengths of the same types of units.

Note that in some theaters there may be different types of infantry units, with varying degrees of armor and artillery assets available. These different types of units should be tracked separately if the optional Step 4 is used.

STEP 2: SITUATIONAL UNIT MULTIPLIER BY TYPE UNIT

The situational unit multipliers are obtained from a table similar to Table 3.1, but the table varies by type unit rather than by category of weapon. The rows of this table are the same as in Table 3.1, representing nine types of battles and four types of terrain. Tables A.2 (for defense) and A.3 (for attack) show 12 rows of multipliers for sample type units based upon Tables 3.1 and 3.2.

STEP 3: RAW SITUATIONAL UNIT STRENGTH

Row 1 is multiplied by row 2 to obtain the situational unit strength in situational equivalent divisions (SEDs).

STEP 4: UNIT LOSS AND SHORTAGE FORCE MODIFIER

This optional step attempts to account for the effects of disproportionate casualty distribution within different types of units. For each category of unit, determine the average

Table A.2

Type Unit Multipliers for the Defense

Type of Battle	Type Terrain	Standard U.S. Armor Division	Standard U.S. Light Infantry Division	Soviet Tank Division	Standard MRD Division
Breakthrough	Open	0.66	0.41	0.67	0.62
Breakthrough	Mixed	0.62	0.45	0.62	0.59
Breakthrough	Rough	0.48	0.55	0.47	0.48
Breakthrough	Mount	0.43	0.59	0.42	0.45
Meeting	Open	1.00	1.00	1.00	1.00
Meeting	Mixed	0.92	1.09	0.91	0.94
Meeting	Rough	0.66	1.36	0.63	0.74
Meeting	Mount	0.58	1.45	0.53	0.68
Fortified	Open	1.52	2.47	1.47	1.64
Fortified	Mixed	1.44	2.61	1.38	1.58
Fortified	Rough	1.19	3.03	1.09	1.40
Fortified	Mount	1.10	3.17	1.00	1.33

Table A.3

Type Unit Multipliers for the Attack

Type of Battle	Type Terrain	Standard U.S. Armor Division	Standard U.S. Light Infantry Division	Standard Soviet Tank Division	Standard MRD Division
Breakthrough	Open	1.41	0.37	1.44	1.25
Breakthrough	Mixed	1.27	0.46	1.29	1.14
Breakthrough	Rough	0.83	0.75	0.82	0.80
Breakthrough	Mount	0.68	0.84	0.66	0.68
Meeting	Open	1.00	1.00	1.00	1.00
Meeting	Mixed	0.91	1.08	0.90	0.93
Meeting	Rough	0.65	1.31	0.61	0.72
Meeting	Mount	0.56	1.39	0.52	0.65
Fortified	Open	0.65	0.66	0.67	0.68
Fortified	Mixed	0.59	0.72	0.60	0.63
Fortified	Rough	0.41	0.87	0.40	0.49
Fortified	Mount	0.35	0.92	0.34	0.44

unit state. Then compare the average unit state for each type of unit to a series of thresholds that determine the state at which this type of unit no longer has each basic combined arms platform and killing potential.

For example, a non-U.S. NATO infantry unit may not have a significant amount of armor remaining after 20 percent casualties, and may not have a significant amount of artillery after 40 percent casualties. Similarly, a Soviet division may not have the significant amount of infantry after 25 percent casualties, and may have a limited amount of artillery after 50 percent casualties. A U.S. light infantry division is automatically short of armor assets even at 100 percent, but may be short of anti-armor strength at 75 percent strength. See Table A.4 for an example of a RAND-ABEL table to determine platform and ability shortage as a function of unit strength. (We may also prefer to make this calculation for each unit individually, before summing the distinct units together as shown in Step 1.)

Table A.4

Sample RAND-ABEL Table Defining Shortages by Unit State

Type Unit	Unit State / /	Short Armor	Short Inf	Short Arty	Short Anti-Armor	Short Anti-Soft	Short Anti-Arty	Unit Wiped Out
U.S.-LID	>0.85	Yes	No	No	No	No	No	No
U.S.-LID	>0.75	Yes	No	No	No	No	Yes	No
U.S.-LID	>0.30	Yes	No	Yes	Yes	No	Yes	No
U.S.-LID	<=0.30	Yes	Yes	Yes	Yes	Yes	Yes	Yes
[Table continues for different types of units.]								

NOTE: See Appendix B for a brief discussion of how to read RAND-ABEL tables.

Note that the shortages defined above imply that a significant amount of platform or killing potential no longer remains in that type of *unit*. However, there may be enough strength in each category of platform or ability to cover the shortages across the entire *force* engaged in this battle. Therefore, all of the types of units should be examined to determine if there are shortages in platform or ability across *all* types of units engaged in this type of battle. If there are, then the force as a whole has a shortage in those platforms and abilities.

If such shortages exist, the effect should be determined as a function of the type of battle and type of terrain and the appropriate multiplier applied to the whole force. A sample RAND-ABEL table for this process is shown in Table A.5.

The dash or "—" mark indicates that the value of this variable does not matter in this case. Rather than defining a very large table that includes all 2304 cases (9 types of battles multiplied by 4 types of terrain multiplied by 64 combinations of the 6 shortages), one can include only the most important cases in the table, as shown in some rows of this example. Since the types of engagements and terrain are ranked from most attacker-favorable to most defender-favorable, one can further reduce the size of the table by using the RAND-ABEL feature of comparing enumerated variables. For example, one can make a statement like "If the terrain is less than or equal to Rough," by placing "<=Rough" in the table.

Note that this less-detailed SFS methodology ignores the density or frontage calculations entirely.

Table A.5

Sample RAND-ABEL Table Defining Effects of Shortages[a]

Type Terrain	Type Battle	Force Short Armor	Force Short Inf	Force Short Arty	Force Short Anti-Armor	Force Short Anti-Soft	Force / Short / Anti- / Arty /	Final Force Mult
Open	Breakthrough	Yes	—	—	Yes	—	—	0.25
Open	Breakthrough	Yes	—	—	No	—	—	0.40
Mixed	Delay	Yes	—	—	Yes	—	—	0.30
Mixed	Delay	Yes	—	—	No	—	—	0.50
Mixed	Delay	No	—	Yes	No	—	—	0.90
Mixed	Delay	No	—	No	No	—	—	1.00
Rough	Prep-def	Yes	No	Yes	No	No	Yes	0.60
Rough	Prep-def	Yes	No	Yes	Yes	No	Yes	0.50

NOTE: Table continues for different cases not listed above.

[a]This sample is based on the defending force.

STEP 5: FINAL SITUATIONAL FORCE STRENGTH

The total of row 3 is multiplied by the number in row 4 to obtain the final situational force strength in SEDs. Use the same combat assessment procedures described in Section 5. Ignore any casualty distribution calculations, as they are accounted for in Step 4 above.

Appendix B
HOW TO READ RAND-ABEL TABLES

RAND-ABEL tables usually consist of four elements. The first element is a comment, the second is a header, the third is the body of the table, and the last part is the end of the table statement. Anything between brackets [...] is considered to be comments and not executable code. These brackets may appear anywhere before, in the middle, or after a table (see Table B.1).

The table header consists of the statement "Decision Table" followed by an optional table name comment, and the required input and output variable names to be used in the table. In the sample RAND-ABEL table, there are three input variables (A, B, and C), and two output variables (X and Y). Anything to the left of the slash marks (/) is an input variable, while anything to the right is an output variable. Equal signs (=) in a row delimit the end of the variable definition and the beginning of the body of the table that contains the values of these variables that will be examined. The final delimiter at the end of the row of equal signs is a period.

The main body of the table contains the values for each of the variables that will be examined. Each row is examined sequentially. The first row is read "if input-variable-A is equal to value-A-1 and input-variable-B is equal to value-B-1 and input-variable-C is equal to

Table B.1

Sample RAND-ABEL Table

Decision Table [unique table name]				
Input- Variable-A	Input- Variable-B	Input / Variable-C /	Output- Variable-X	Output- Variable-Y =.
Value-A-1	Value-B-1	Value-C-1	Value-X-1	Value-Y-2
Value-A-1	Value-B-1	Value-C-2	Value-X-2	Value-Y-3
Value-A-1	Value-B-2	Value-C-1	Value-X-3	Value-Y-4
Value-A-1	Value-B-2	Value-C-2	Value-X-4	Value-Y-6
Value-A-2	Value-B-1	Value-C-1	Value-X-5	Value-Y-7
Value-A-2	Value-B-1	Value-C-2	Value-X-6	Value-Y-8
Value-A-2	Value-B-2	Value-C-1	Value-X-7	Value-Y-4
Value-A-2	Value-B-2	Value-C-2	Value-X-8	Value-Y-5
Value-A-3	++	—	Value-X-9	Value-Y-6
—	++	—	Value-X-10	Value-Y-7
[End Table].				

NOTE 1: [Comments: Anything between these brackets is a comment and not executable code. They are used to document what is in the table and to provide an audit trail of the reasons or values in the following table.]

value-C-1, then set output-variable-X to value-X-1 and set output-variable-Y to value-Y-2." The table may contain as many rows and columns as the user wishes to define. The first row that registers true simultaneously for all variables on the left-hand side is the row that sets the values of the output variables on the right-hand side. In this kind of table, only one row will set the values of the output variables. Once this row is "triggered," the program exits from this table and proceeds to the next section of code.

The symbols "++" and "—" both mean "I don't care what value the variable in this column has, count it as returning a value of 'true,' thereby allowing that row to 'trigger' regardless of the current value of this variable." For example, in the second-to-last row, as long as input-variable-A is equal to value-A-3, then regardless of the values of input variables "B" and "C," output-variable-X will be set to value-X-9, and output-variable-Y will be set to value-Y-6. The only difference between the two symbols "++" and "—" is that the former is used for variables that use numeric values such as "4.7" or "5," while the latter is used for enumerated variables that use nonnumeric values such as "High," "Blue," or "Bad." In our example, input-variable-B is assumed to be numeric, while the other two input variables are assumed to be nonnumeric. A new version of RAND-ABEL distinguishes "unspecified" (—) from "don't care" (**).

The last part of the table is the "End Table" statement, which determines the end of the values to be considered. Note that the phrase "End Table" is a comment, while the actual end-of-table delimiter is the period. This format is used because it is easier to see an "End Table" comment than a trailing period.

The analyst can modify the existing tables by changing the values of the variables in the main body of the table. In addition, the analyst may prefer to add additional input or output variables to an existing table and define the appropriate values for these additional variables. Finally, the analyst may wish to add more tables to consider additional factors not yet accounted for. The analyst can perform any of these changes even while the model is running.

Of course, some changes are easier to make than others. For example, if one is adding a variable to a table that is defined only for that function, then the change can be made using the RAND-ABEL interpreter while the model is still running. However, if the variable being added should affect, or be affected by, other functions, then the new variable must be added as a global variable. The latter case does require several more steps and requires the model to be recompiled. To help ease the problem, a number of dummy (or not currently used) global variables are defined. The analyst can use these global variables without recompiling, which aids in a faster response time and testing model development concepts.

Appendix C

SAMPLE SPREADSHEET DISPLAYS FOR DEFINING SFS DATA

The following tables are reproduced from the spreadsheet tool used to determine the values of the entries for Tables 3.1 and 3.2. Only Table C.1 is an input to the spreadsheet, while the remaining tables are outputs of the spreadsheet. The source of the weapon values are a new system being developed by RAND as described in Appendix E. The standard U.S. armored division score is 5268.4, as calculated for a deliberate defense in mixed terrain. This value is obtained by summing over all categories of weapons the product of the number of assets times the value of each asset in Table C.1. The frontage or shoulder-space restrictions for armor have been applied in this table, which is why the armor weapons holdings are reduced by the type of terrain.

Given the category multipliers in Tables 3.1 and 3.2, the spreadsheet automatically calculates the percentage contribution of each category of weapon as shown in Table C.2. This table is used to verify that the relative contribution of each category of weapon is reasonable for each combat situation. Tables C.3 through C.5 are similar to Table C.2, but for different types of units. Tables C.6 through C.9 are similar to Tables C.2 through C.5, except they are for units on the offense. It may be useful to the analyst to display the percentage contribution of each category of weapon in each combat situation assessed in the model.

Table C.1

Standard Attacking Unit Weapons and Category Weights

U.S. Armor Div

Terrain	Tanks, IFVs, ARVs	APCs	LR Anti-armor	SR Anti-armor	Mortars, Sm Arms	Arty
Mountain	228	92	0	454	1800	159
Urban	456	184	0	454	1800	159
Rough	570	230	0	454	1800	159
Mixed/open	778	314	0	454	1800	159

U.S. LID

Terrain	Tanks, IFVs, ARVs	APCs	LR Anti-armor	SR Anti-armor	Mortars, Sm Arms	Arty
All	0	0	36	372	3890	62

USSR Tank Div

Terrain	Tanks, IFVs, ARVs	APCs	LR Anti-armor	SR Anti-armor	Mortars, Sm Arms	Arty
Mountain	220	20	9	469	1800	180
Urban	440	40	9	469	1800	180
Rough	586	54	9	469	1800	180
Mixed/open	674	63	9	469	1800	180

USSR MR Div

Terrain	Tanks, IFVs, ARVs	APCs	LR Anti-armor	SR Anti-armor	Mortars, Sm Arms	Arty
Mountain	134	106	72	610	2800	198
Urban	238	212	72	610	2800	198
Rough	342	271	72	610	2800	198
Mixed/open	342	271	72	610	2800	198

Average Scores

Side	Tanks, IFVs, ARVs	APCs	LR Anti-armor	SR Anti-armor	Mortars, Sm Arms	Arty
Blue	5.00	1.00	1.20	0.30	0.18	3.80
Red	4.00	1.00	1.00	0.25	0.15	2.50

Table C.2

Percentage Contribution by Category for U.S. Armored Division on the Defense

Type of Battle	Terrain	Tank, IFV, ARV	APC	LR A Arm	SR A Arm	Sml Arms	Arty	Total
Breakthrough	Open	83.0	8.7	0	1.5	3.5	3.2	100
Breakthrough	Mixed	82.1	8.6	0	1.8	4.3	3.2	100
Breakthrough	Rough	79.7	8.3	0	2.5	6.0	3.4	100
Breakthrough	Urban	76.0	6.1	0	4.3	10.1	3.5	100
Breakthrough	Mount	61.9	6.5	0	7.4	17.6	6.6	100
Withdrawal	Open	79.6	8.4	0	1.5	3.6	6.9	100
Withdrawal	Mixed	78.7	8.3	0	1.8	4.4	6.8	100
Withdrawal	Rough	76.1	8.0	0	2.6	6.2	7.2	100
Withdrawal	Urban	72.2	5.8	0	4.3	10.3	7.4	100
Withdrawal	Mount	56.5	5.9	0	7.2	17.1	13.3	100
Delay	Open	78.2	8.2	0	1.4	3.4	8.8	100
Delay	Mixed	77.3	8.1	0	1.7	4.1	8.7	100
Delay	Rough	74.8	7.8	0	2.4	5.8	9.2	100
Delay	Urban	71.0	5.7	0	4.0	9.6	9.6	100
Delay	Mount	54.8	5.8	0	6.7	15.9	16.9	100
Hasty	Open	77.1	4.4	0	1.9	4.6	12.0	100
Hasty	Mixed	76.0	4.3	0	2.3	5.5	11.8	100
Hasty	Rough	72.7	4.1	0	3.2	7.7	12.3	100
Hasty	Urban	65.3	5.3	0	5.1	12.2	12.1	100
Hasty	Mount	48.9	2.8	0	8.2	19.5	20.7	100
Deliberate	Open	76.4	4.3	0	2.2	5.2	11.9	100
Deliberate	Mixed	75.2	4.2	0	2.6	6.3	11.7	100
Deliberate	Rough	71.5	4.0	0	3.6	8.7	12.1	100
Deliberate	Urban	63.7	5.1	0	5.7	13.6	11.8	100
Deliberate	Mount	47.0	2.7	0	9.0	21.4	19.9	100
Prepared	Open	75.4	4.3	0	2.6	6.1	11.7	100
Prepared	Mixed	74.0	4.2	0	3.1	7.3	11.5	100
Prepared	Rough	70.0	3.9	0	4.2	10.0	11.9	100
Prepared	Urban	61.6	5.0	0	6.5	15.5	11.4	100
Prepared	Mount	44.6	2.5	0	10.1	24.0	18.9	100
Fortified	Open	75.5	4.3	0	2.5	6.0	11.7	100
Fortified	Mixed	74.1	4.2	0	3.0	7.2	11.5	100
Fortified	Rough	70.1	4.0	0	4.2	9.9	11.9	100
Fortified	Urban	61.8	5.0	0	6.5	15.4	11.5	100
Fortified	Mount	44.8	2.5	0	10.0	23.7	19.0	100
Static	Open	72.4	5.8	0	1.5	3.5	16.9	100
Static	Mixed	71.6	5.8	0	1.8	4.2	16.7	100
Static	Rough	68.7	5.5	0	2.5	5.8	17.5	100
Static	Urban	63.7	5.1	0	4.0	9.5	17.7	100
Static	Mount	46.1	3.7	0	6.2	14.7	29.3	100
Meeting	Open	80.1	6.5	0	1.8	3.8	7.8	100
Meeting	Mixed	79.1	6.4	0	2.2	4.6	7.7	100
Meeting	Rough	76.3	6.1	0	3.1	6.5	8.1	100
Meeting	Urban	70.6	5.7	0	5.0	10.5	8.2	100
Meeting	Mount	55.1	4 4	0	8.3	17.5	14.6	100

Table C.3

Percentage Contribution by Category for U.S. Light Infantry Division on the Defense

Type of Battle	Terrain	Tank, IFV, ARV	APC	LR A Arm	SR A Arm	Sml Arms	Arty	Total
Breakthrough	Open	0	0	5.3	11.4	71.5	11.8	100
Breakthrough	Mixed	0	0	4.6	11.8	73.8	9.9	100
Breakthrough	Rough	0	0	3.6	12.2	76.5	7.7	100
Breakthrough	Urban	0	0	1.4	12.9	80.7	5.1	100
Breakthrough	Mount	0	0	2.6	12.7	79.4	5.3	100
Withdrawal	Open	0	0	4.7	10.1	63.4	21.7	100
Withdrawal	Mixed	0	0	4.1	10.6	66.6	18.7	100
Withdrawal	Rough	0	0	3.3	11.2	70.6	14.8	100
Withdrawal	Urban	0	0	1.3	12.2	76.5	10.0	100
Withdrawal	Mount	0	0	2.4	12.0	75.1	10.5	100
Delay	Open	0	0	4.3	9.4	58.7	27.6	100
Delay	Mixed	0	0	3.8	9.9	62.3	23.9	100
Delay	Rough	0	0	3.2	10.7	66.9	19.3	100
Delay	Urban	0	0	1.3	11.8	73.7	13.2	100
Delay	Mount	0	0	2.3	11.5	72.3	13.9	100
Hasty	Open	0	0	4.3	9.4	58.7	27.6	100
Hasty	Mixed	0	0	3.8	9.9	62.3	23.9	100
Hasty	Rough	0	0	3.2	10.7	66.9	19.3	100
Hasty	Urban	0	0	1.3	11.8	73.7	13.2	100
Hasty	Mount	0	0	2.3	11.5	72.3	13.9	100
Deliberate	Open	0	0	4.5	9.7	60.8	25.0	100
Deliberate	Mixed	0	0	4.0	10.2	64.2	21.6	100
Deliberate	Rough	0	0	3.2	10.9	68.5	17.3	100
Deliberate	Urban	0	0	1.3	12.0	75.0	11.8	100
Deliberate	Mount	0	0	2.4	11.7	73.5	12.4	100
Prepared	Open	0	0	4.7	10.1	63.2	22.0	100
Prepared	Mixed	0	0	4.1	10.6	66.4	18.9	100
Prepared	Rough	0	0	3.3	11.2	70.4	15.0	100
Prepared	Urban	0	0	1.3	12.2	76.4	10.1	100
Prepared	Mount	0	0	2.4	11.9	75.0	10.7	100
Fortified	Open	0	0	4.7	10.0	63.1	22.2	100
Fortified	Mixed	0	0	4.1	10.6	66.2	19.1	100
Fortified	Rough	0	0	3.3	11.2	70.3	15.2	100
Fortified	Urban	0	0	1.3	12.2	76.3	10.3	100
Fortified	Mount	0	0	2.4	11.9	74.9	10.8	100
Static	Open	0	0	3.5	7.5	47.3	41.7	100
Static	Mixed	0	0	3.2	8.2	51.5	37.1	100
Static	Rough	0	0	2.7	9.1	57.2	30.9	100
Static	Urban	0	0	1.1	10.5	66.1	22.2	100
Static	Mount	0	0	2.1	10.3	64.4	23.2	100
Meeting	Open	0	0	5.4	11.0	61.2	22.5	100
Meeting	Mixed	0	0	4.7	11.5	64.4	19.3	100
Meeting	Rough	0	0	3.8	12.3	68.5	15.4	100
Meeting	Urban	0	0	1.5	13.4	74.6	10.5	100
Meeting	Mount	0	0	2.8	13.1	73.1	11.0	100

Table C.4

Percentage Contribution by Category for Soviet Tank Division on the Defense

Type of Battle	Terrain	Tank, IFV, ARV	APC	LR A Arm	SR A Arm	Sml Arms	Arty	Total
Breakthrough	Open	87.1	2.6	0.2	1.9	4.5	3.6	100
Breakthrough	Mixed	85.9	2.6	0.2	2.3	5.4	3.6	100
Breakthrough	Rough	83.8	2.5	0.2	3.0	7.0	3.5	100
Breakthrough	Urban	79.4	1.8	0.1	4.7	10.7	3.3	100
Breakthrough	Mount	64.8	1.9	0.3	8.1	18.7	6.2	100
Withdrawal	Open	83.1	2.5	0.2	2.0	4.5	7.7	100
Withdrawal	Mixed	81.9	2.5	0.2	2.4	5.5	7.6	100
Withdrawal	Rough	79.8	2.4	0.2	3.1	7.1	7.4	100
Withdrawal	Urban	75.5	1.7	0.1	4.7	10.9	7.0	100
Withdrawal	Mount	59.2	1.8	0.3	7.9	18.2	12.6	100
Delay	Open	81.4	2.5	0.2	1.8	4.2	9.9	100
Delay	Mixed	80.3	2.4	0.2	2.2	5.1	9.7	100
Delay	Rough	78.4	2.4	0.2	2.9	6.7	9.5	100
Delay	Urban	74.4	1.7	0.1	4.4	10.2	9.1	100
Delay	Mount	57.6	1.7	0.3	7.3	16.9	16.1	100
Hasty	Open	77.6	1.3	0.2	2.4	5.6	12.9	100
Hasty	Mixed	76.2	1.2	0.2	2.9	6.7	12.7	100
Hasty	Rough	73.9	1.2	0.2	3.7	8.6	12.3	100
Hasty	Urban	68.3	1.6	0.1	5.6	12.9	11.5	100
Hasty	Mount	50.4	0.8	0.4	8.8	20.3	19.3	100
Deliberate	Open	76.7	1.3	0.3	2.7	6.3	12.8	100
Deliberate	Mixed	75.2	1.2	0.3	3.3	7.5	12.5	100
Deliberate	Rough	72.6	1.2	0.2	4.2	9.7	12.1	100
Deliberate	Urban	66.5	1.5	0.1	6.2	14.4	11.2	100
Deliberate	Mount	48.3	0.8	0.4	9.7	22.3	18.6	100
Prepared	Open	75.4	1.2	0.3	3.2	7.3	12.6	100
Prepared	Mixed	73.7	1.2	0.3	3.8	8.7	12.3	100
Prepared	Rough	70.7	1.2	0.3	4.8	11.2	11.8	100
Prepared	Urban	64.1	1.5	0.2	7.1	16.4	10.8	100
Prepared	Mount	45.6	0.7	0.4	10.8	24.9	17.5	100
Fortified	Open	75.5	1.2	0.3	3.1	7.2	12.6	100
Fortified	Mixed	73.8	1.2	0.3	3.7	8.6	12.3	100
Fortified	Rough	70.9	1.2	0.3	4.8	11.0	11.8	100
Fortified	Urban	64.3	1.5	0.2	7.0	16.2	10.8	100
Fortified	Mount	45.9	0.7	0.4	10.7	24.7	17.6	100
Static	Open	73.6	1.7	0.2	1.8	4.2	18.4	100
Static	Mixed	72.6	1.7	0.2	2.2	5.1	18.2	100
Static	Rough	70.9	1.7	0.2	2.9	6.6	17.8	100
Static	Urban	67.0	1.5	0.1	4.4	10.1	16.9	100
Static	Mount	48.4	1.1	0.3	6.8	15.6	27.9	100
Meeting	Open	82.3	1.9	0.2	2.3	4.7	8.6	100
Meeting	Mixed	81.0	1.9	0.2	2.8	5.7	8.4	100
Meeting	Rough	78.8	1.8	0.2	3.6	7.4	8.2	100
Meeting	Urban	73.8	1.7	0.1	5.5	11.2	7.7	100
Meeting	Mount	57.1	1.3	0.4	9.0	18.4	13.7	100

Table C.5

Percentage Contribution by Category for Soviet MRD on the Defense

Type of Battle	Terrain	Tank, IFV, ARV	APC	LR A Arm	SR A Arm	Sml Arms	Arty	Total
Breakthrough	Open	62.7	16.2	2.0	3.6	9.8	5.7	100
Breakthrough	Mixed	60.9	15.7	2.0	4.2	11.7	5.5	100
Breakthrough	Rough	57.8	14.9	1.9	5.4	14.8	5.2	100
Breakthrough	Urban	56.0	11.1	1.0	7.3	20.2	4.4	100
Breakthrough	Mount	40.1	10.3	2.6	10.7	29.4	6.9	100
Withdrawal	Open	58.1	15.0	2.0	3.5	9.7	11.7	100
Withdrawal	Mixed	56.4	14.5	2.0	4.2	11.5	11.3	100
Withdrawal	Rough	53.6	13.8	1.9	5.3	14.6	10.8	100
Withdrawal	Urban	52.2	10.3	1.0	7.3	20.0	9.2	100
Withdrawal	Mount	36.0	9.2	2.5	10.2	28.2	13.8	100
Delay	Open	56.5	14.5	1.9	3.3	9.0	14.9	100
Delay	Mixed	54.9	14.1	1.8	3.9	10.7	14.5	100
Delay	Rough	52.4	13.5	1.8	5.0	13.6	13.8	100
Delay	Urban	51.4	10.2	0.9	6.8	18.8	11.8	100
Delay	Mount	35.2	9.0	2.4	9.5	26.3	17.7	100
Hasty	Open	54.2	7.5	2.5	4.3	11.9	19.6	100
Hasty	Mixed	52.3	7.2	2.4	5.1	14.0	18.9	100
Hasty	Rough	49.1	6.8	2.3	6.4	17.6	17.8	100
Hasty	Urban	44.9	8.9	1.1	8.2	22.6	14.2	100
Hasty	Mount	30.1	4.2	2.8	11.2	30.9	20.8	100
Deliberate	Open	52.8	7.3	2.7	4.8	13.3	19.1	100
Deliberate	Mixed	50.7	7.0	2.7	5.7	15.6	18.4	100
Deliberate	Rough	47.3	6.6	2.5	7.0	19.4	17.1	100
Deliberate	Urban	43.0	8.5	1.2	9.0	24.7	13.6	100
Deliberate	Mount	28.3	3.9	3.0	12.1	33.2	19.6	100
Prepared	Open	50.9	7.1	3.1	5.5	15.1	18.4	100
Prepared	Mixed	48.6	6.7	3.0	6.4	17.6	17.6	100
Prepared	Rough	45.0	6.2	2.9	7.9	21.8	16.3	100
Prepared	Urban	40.4	8.0	1.3	10.0	27.5	12.8	100
Prepared	Mount	26.0	3.6	3.2	13.1	36.1	18.0	100
Fortified	Open	51.0	7.1	3.1	5.4	15.0	18.5	100
Fortified	Mixed	48.8	6.8	3.0	6.3	17.5	17.6	100
Fortified	Rough	45.2	6.3	2.8	7.8	21.6	16.3	100
Fortified	Urban	40.6	8.0	1.3	9.9	27.3	12.9	100
Fortified	Mount	26.2	3.6	3.2	13.0	35.8	18.1	100
Static	Open	49.6	9.8	1.8	3.2	8.7	26.9	100
Static	Mixed	48.3	9.6	1.8	3.8	10.4	26.2	100
Static	Rough	46.1	9.1	1.7	4.8	13.2	25.0	100
Static	Urban	44.6	8.8	0.9	6.5	18.0	21.2	100
Static	Mount	29.2	5.7	2.2	8.7	24.0	30.3	100
Meeting	Open	58.3	11.6	2.5	4.2	10.3	13.2	100
Meeting	Mixed	56.5	11.2	2.5	5.0	12.1	12.8	100
Meeting	Rough	53.4	10.6	2.4	6.3	15.3	12.1	100
Meeting	Urban	50.3	10.0	1.2	8.3	20.3	10.0	100
Meeting	Mount	34.8	6.9	3.1	11.7	28.6	15.0	100

Table C.6

Percentage Contribution by Category for U.S. Armored Division on the Attack

Type of Battle	Terrain	Tank, IFV, ARV	APC	LR A Arm	SR A Arm	Sml Arms	Arty	Total
Breakthrough	Open	85.5	9.0	0	0.6	1.3	3.6	100
Breakthrough	Mixed	84.9	8.9	0	0.8	1.6	3.8	100
Breakthrough	Rough	73.7	7.7	0	2.7	5.7	10.1	100
Breakthrough	Urban	69.9	5.6	0	4.5	9.6	10.4	100
Breakthrough	Mount	53.3	5.6	0	7.4	15.6	18.2	100
Withdrawal	Open	83.4	8.8	0	0.9	1.8	5.2	100
Withdrawal	Mixed	82.6	8.7	0	1.1	2.3	5.3	100
Withdrawal	Rough	73.2	7.7	0	2.8	5.9	10.4	100
Withdrawal	Urban	69.2	5.6	0	4.7	9.8	10.7	100
Withdrawal	Mount	52.5	5.5	0	7.5	15.9	18.5	100
Delay	Open	80.6	8.5	0	1.2	2.5	7.2	100
Delay	Mixed	79.6	8.3	0	1.5	3.2	7.4	100
Delay	Rough	74.7	7.8	0	2.6	5.4	9.5	100
Delay	Urban	71.0	5.7	0	4.3	9.1	9.9	100
Delay	Mount	54.8	5.7	0	7.1	15.0	17.4	100
Hasty	Open	78.0	4.4	0	1.9	4.1	11.6	100
Hasty	Mixed	76.3	4.3	0	2.4	5.1	11.9	100
Hasty	Rough	69.1	3.9	0	4.0	8.4	14.6	100
Hasty	Urban	61.5	5.0	0	6.2	13.1	14.3	100
Hasty	Mount	44.3	2.5	0	9.5	20.2	23.5	100
Deliberate	Open	78.0	4.4	0	1.9	4.1	11.6	100
Deliberate	Mixed	76.3	4.3	0	2.4	5.1	11.9	100
Deliberate	Rough	69.1	3.9	0	4.0	8.4	14.6	100
Deliberate	Urban	61.5	5.0	0	6.2	13.1	14.3	100
Deliberate	Mount	44.3	2.5	0	9.5	20.2	23.5	100
Prepared	Open	77.5	4.4	0	2.5	4.0	11.5	100
Prepared	Mixed	75.8	4.3	0	3.1	5.0	11.8	100
Prepared	Rough	68.2	3.9	0	5.1	8.3	14.5	100
Prepared	Urban	60.3	4.9	0	8.0	12.9	14.0	100
Prepared	Mount	43.0	2.4	0	12.2	19.6	22.8	100
Fortified	Open	77.5	4.4	0	2.5	4.0	11.5	100
Fortified	Mixed	75.7	4.3	0	3.2	5.0	11.8	100
Fortified	Rough	68.2	3.9	0	5.2	8.3	14.5	100
Fortified	Urban	60.2	4.9	0	8.1	12.8	14.0	100
Fortified	Mount	43.0	2.4	0	12.3	19.5	22.8	100
Static	Open	73.5	5.9	0	1.3	3.0	16.4	100
Static	Mixed	72.1	5.8	0	1.6	3.8	16.8	100
Static	Rough	65.2	5.3	0	2.6	6.2	20.7	100
Static	Urban	60.1	4.8	0	4.2	10.0	20.9	100
Static	Mount	42.0	3.4	0	6.3	14.9	33.4	100
Meeting	Open	80.4	6.5	0	1.7	3.5	8.0	100
Meeting	Mixed	79.0	6.4	0	2.1	4.4	8.2	100
Meeting	Rough	72.9	5.9	0	3.5	7.4	10.3	100
Meeting	Urban	66.8	5.4	0	5.6	11.9	10.3	100
Meeting	Mount	50.2	4.1	0	9.0	19.0	17.7	100

Table C.7

Percentage Contribution by Category for U.S. Light Infantry Division on the Attack

Type of Battle	Terrain	Tank, IFV, ARV	APC	LR A Arm	SR A Arm	Sml Arms	Arty	Total
Breakthrough	Open	0	0	5.1	10.0	56.0	28.8	100
Breakthrough	Mixed	0	0	4.4	10.7	59.8	25.1	100
Breakthrough	Rough	0	0	3.6	11.6	64.5	20.3	100
Breakthrough	Urban	0	0	1.5	12.8	71.6	14.1	100
Breakthrough	Mount	0	0	2.7	12.6	70.0	14.7	100
Withdrawal	Open	0	0	5.1	10.0	56.0	28.8	100
Withdrawal	Mixed	0	0	4.4	10.7	59.8	25.1	100
Withdrawal	Rough	0	0	3.6	11.6	64.5	20.3	100
Withdrawal	Urban	0	0	1.5	12.8	71.6	14.1	100
Withdrawal	Mount	0	0	2.7	12.6	70.0	14.7	100
Delay	Open	0	0	5.1	10.0	56.0	28.8	100
Delay	Mixed	0	0	4.4	10.7	59.8	25.1	100
Delay	Rough	0	0	3.6	11.6	64.5	20.3	100
Delay	Urban	0	0	1.5	12.8	71.6	14.1	100
Delay	Mount	0	0	2.7	12.6	70.0	14.7	100
Hasty	Open	0	0	5.1	10.0	56.0	28.8	100
Hasty	Mixed	0	0	4.4	10.7	59.8	25.1	100
Hasty	Rough	0	0	3.6	11.6	64.5	20.3	100
Hasty	Urban	0	0	1.5	12.8	71.6	14.1	100
Hasty	Mount	0	0	2.7	12.6	70.0	14.7	100
Deliberate	Open	0	0	5.1	10.0	56.0	28.8	100
Deliberate	Mixed	0	0	4.4	10.7	59.8	25.1	100
Deliberate	Rough	0	0	3.6	11.6	64.5	20.3	100
Deliberate	Urban	0	0	1.5	12.8	71.6	14.1	100
Deliberate	Mount	0	0	2.7	12.6	70.0	14.7	100
Prepared	Open	0	0	5.0	12.8	54.3	27.9	100
Prepared	Mixed	0	0	4.2	13.6	57.8	24.3	100
Prepared	Rough	0	0	3.5	14.7	62.2	19.6	100
Prepared	Urban	0	0	1.4	16.2	68.8	13.5	100
Prepared	Mount	0	0	2.6	15.9	67.4	14.2	100
Fortified	Open	0	0	4.9	13.0	54.2	27.9	100
Fortified	Mixed	0	0	4.2	13.8	57.7	24.3	100
Fortified	Rough	0	0	3.5	14.8	62.1	19.6	100
Fortified	Urban	0	0	1.4	16.4	68.7	13.5	100
Fortified	Mount	0	0	2.6	16.1	67.2	14.1	100
Static	Open	0	0	3.5	7.2	45.0	44.4	100
Static	Mixed	0	0	3.0	7.9	49.3	39.8	100
Static	Rough	0	0	2.6	8.8	55.2	33.4	100
Static	Urban	0	0	1.1	10.3	64.4	24.3	100
Static	Mount	0	0	2.0	10.0	62.7	25.3	100
Meeting	Open	0	0	5.4	10.7	59.5	24.5	100
Meeting	Mixed	0	0	4.6	11.3	62.9	21.2	100
Meeting	Rough	0	0	3.8	12.1	67.2	17.0	100
Meeting	Urban	0	0	1.5	13.2	73.7	11.6	100
Meeting	Mount	0	0	2.8	12.9	72.1	12.1	100

Table C.8

Percentage Contribution by Category for Soviet Tank Division on the Attack

Type of Battle	Terrain	Tank, IFV, ARV	APC	LR A Arm	SR A Arm	Sml Arms	Arty	Total
Breakthrough	Open	90.6	2.8	0.1	0.8	1.6	4.1	100
Breakthrough	Mixed	89.8	2.7	0.1	1.0	2.1	4.3	100
Breakthrough	Rough	78.5	2.4	0.2	3.0	6.2	9.7	100
Breakthrough	Urban	72.0	1.6	0.1	5.2	10.7	10.4	100
Breakthrough	Mount	54.5	1.6	0.4	8.4	17.2	17.9	100
Withdrawal	Open	87.9	2.7	0.1	1.1	2.3	5.9	100
Withdrawal	Mixed	86.9	2.6	0.1	1.4	2.9	6.0	100
Withdrawal	Rough	78.0	2.3	0.2	3.1	6.4	10.0	100
Withdrawal	Urban	71.3	1.6	0.1	5.3	10.9	10.6	100
Withdrawal	Mount	53.6	1.6	0.4	8.6	17.6	18.3	100
Delay	Open	84.5	2.6	0.2	1.6	3.2	8.1	100
Delay	Mixed	83.1	2.5	0.2	2.0	4.0	8.3	100
Delay	Rough	79.5	2.4	0.2	2.9	5.9	9.2	100
Delay	Urban	73.3	1.7	0.1	4.9	10.1	9.8	100
Delay	Mount	56.2	1.7	0.3	8.1	16.5	17.2	100
Hasty	Open	78.6	1.3	0.2	2.4	4.9	12.5	100
Hasty	Mixed	76.6	1.3	0.2	3.0	6.1	12.8	100
Hasty	Rough	71.7	1.2	0.3	4.3	8.8	13.8	100
Hasty	Urban	62.8	1.4	0.2	7.1	14.5	14.1	100
Hasty	Mount	44.1	0.7	0.4	10.6	21.6	22.5	100
Deliberate	Open	78.6	1.3	0.2	2.4	4.9	12.5	100
Deliberate	Mixed	76.6	1.3	0.2	3.0	6.1	12.8	100
Deliberate	Rough	71.7	1.2	0.3	4.3	8.8	13.8	100
Deliberate	Urban	62.8	1.4	0.2	7.1	14.5	14.1	100
Deliberate	Mount	44.1	0.7	0.4	10.6	21.6	22.5	100
Prepared	Open	78.0	1.3	0.2	3.1	4.9	12 5	100
Prepared	Mixed	75.9	1.2	0.2	3.9	6.1	12.7	100
Prepared	Rough	70.7	1.1	0.3	5.6	8.7	13.6	100
Prepared	Urban	61.5	1.4	0.2	9.1	14.1	13.8	100
Prepared	Mount	42.7	0.7	0.4	13.5	20.9	21.8	100
Fortified	Open	78.0	1.3	0.2	3.2	4.9	12.4	100
Fortified	Mixed	75.8	1.2	0.2	4.0	6.1	12.7	100
Fortified	Rough	70.7	1.1	0.3	5.7	8.7	13.6	100
Fortified	Urban	61.4	1.4	0.2	9.2	14.1	13.7	100
Fortified	Mount	42.6	0.7	0.4	13.6	20.9	21.8	100
Static	Open	74.9	1.8	0.2	1.6	3.7	17.9	100
Static	Mixed	73.2	1.7	0.2	2.0	4.6	18.3	100
Static	Rough	68.9	1.6	0.2	2.9	6.6	19.8	100
Static	Urban	61.8	1.4	0.1	4.8	11.1	20.7	100
Static	Mount	42.6	1.0	0.3	7.1	16.3	32.7	100
Meeting	Open	82.6	1.9	0.2	2.1	4.3	8.8	100
Meeting	Mixed	80.9	1.9	0.2	2.6	5.4	9.0	100
Meeting	Rough	76.5	1.8	0.2	3.8	7.8	9.8	100
Meeting	Urban	68.5	1.6	0.1	6.4	13.1	10.2	100
Meeting	Mount	50.5	1.1	0.4	10.1	20.6	17.2	100

Table C.9

Percentage Contribution by Category for Soviet MRD on the Attack

Type of Battle	Terrain	Tank, IFV, ARV	APC	LR A Arm	SR A Arm	Sml Arms	Arty	Total
Breakthrough	Open	69.1	17.8	1.0	1.5	3.8	6.8	100
Breakthrough	Mixed	67.8	17.5	1.0	1.9	4.8	7.0	100
Breakthrough	Rough	55.0	14.2	1.8	4.7	11.6	12.8	100
Breakthrough	Urban	46.8	10.4	1.1	8.1	19.9	13.7	100
Breakthrough	Mount	32.6	8.4	2.8	10.7	26.2	19.3	100
Withdrawal	Open	65.2	16.8	1.3	2.1	5.2	9.4	100
Withdrawal	Mixed	63.6	16.4	1.3	2.7	6.5	9.6	100
Withdrawal	Rough	54.3	14.0	1.9	4.8	11.9	13.1	100
Withdrawal	Urban	46.0	10.3	1.2	8.3	20.3	14.0	100
Withdrawal	Mount	31.9	8.2	2.8	10.9	26.6	19.6	100
Delay	Open	60.4	15.5	1.8	2.8	7.0	12.5	100
Delay	Mixed	58.4	15.0	1.8	3.5	8.6	12.7	100
Delay	Rough	56.1	14.5	1.7	4.5	11.0	12.2	100
Delay	Urban	48.1	10.7	1.1	7.8	19.1	13.1	100
Delay	Mount	33.9	8.7	2.7	10.4	25.5	18.8	100
Hasty	Open	55.4	7.7	2.7	4.4	10.7	19.2	100
Hasty	Mixed	52.7	7.3	2.6	5.3	13.0	19.1	100
Hasty	Rough	49.7	6.9	2.5	6.6	16.3	18.0	100
Hasty	Urban	37.8	8.4	1.4	10.2	25.0	17.2	100
Hasty	Mount	25.2	3.5	3.4	12.9	31.6	23.3	100
Deliberate	Open	55.4	7.7	2.7	4.4	10.7	19.2	100
Deliberate	Mixed	52.7	7.3	2.6	5.3	13.0	19.1	100
Deliberate	Rough	49.7	6.9	2.5	6.6	16.3	18.0	100
Deliberate	Urban	37.8	8.4	1.4	10.2	25.0	17.2	100
Deliberate	Mount	25.2	3.5	3.4	12.9	31.6	23.3	100
Prepared	Open	54.7	7.6	2.7	5.6	10.5	18.9	100
Prepared	Mixed	51.9	7.2	2.6	6.8	12.7	18.8	100
Prepared	Rough	48.7	6.7	2.5	8.6	15.9	17.6	100
Prepared	Urban	36.6	8.1	1.4	13.0	24.2	16.6	100
Prepared	Mount	24.3	3.4	3.2	16.3	30.4	22.4	100
Fortified	Open	54.6	7.6	2.7	5.7	10.5	18.9	100
Fortified	Mixed	51.8	7.2	2.6	6.9	12.7	18.7	100
Fortified	Rough	48.6	6.7	2.5	8.7	15.9	17.6	100
Fortified	Urban	36.5	8.1	1.4	13.2	24.2	16.6	100
Fortified	Mount	24.2	3.3	3.2	16.5	30.3	22.3	100
Static	Open	51.2	10.1	1.6	2.8	7.7	26.6	100
Static	Mixed	49.1	9.7	1.6	3.4	9.4	26.7	100
Static	Rough	47.1	9.3	1.6	4.4	12.0	25.6	100
Static	Urban	38.0	8.5	0.9	7.1	19.6	25.9	100
Static	Mount	25.0	4.9	2.2	8.9	24.4	34.6	100
Meeting	Open	59.0	11.7	2.4	3.9	9.5	13.6	100
Meeting	Mixed	56.5	11.2	2.4	4.7	11.6	13.6	100
Meeting	Rough	53.6	10.6	2.3	6.0	14.6	12.9	100
Meeting	Urban	42.8	9.5	1.3	9.7	23.6	13.0	100
Meeting	Mount	29.4	5.8	3.3	12.6	30.8	18.1	100

Appendix D

COMPARISON OF SAMPLE NON-SFS/SFS RESULTS

CAMPAIGN-ALT currently offers a choice of non-SFS or SFS methodology with the latter as default. (To use the non-SFS methodology, a user may insert the following RAND-ABEL statement in a Control Plan: "Let Referee's Referee-option of Situation-scoring be No.") It is instructive to compare results obtained using non-SFS versus SFS methodology, based upon a scenario run at the 1991 Global War Game sponsored by the U.S. Naval War College.

In the following simple example, one U.S. armored division attacks an Iraqi corps deployed on the Kuwait-Iraqi border. The U.S. armored division is reinforced by corps artillery assets and supported by one wing of F-16C aircraft in the close air support (CAS) role. The Iraqi corps has its normal complement of artillery but no air support. The ground attack begins on day 10 of the simulation and continues for 20 days. Figure D.1 shows a comparison of FLOT location and velocity. Results obtained from the non-SFS methodology

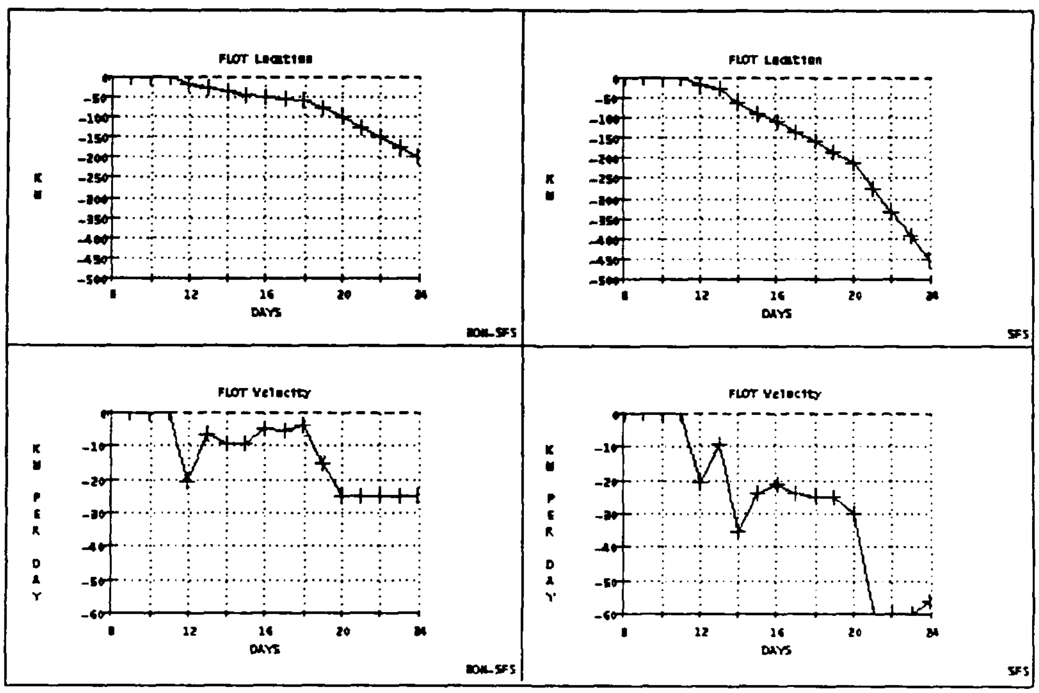

Fig. D.1—FLOT Location and Velocity

are displayed in the left-hand graphics; results using SFS methodology are displayed in the right-hand graphs. At a glance, it is apparent that SFS methodology produced more rapid FLOT movement and much deeper penetration into Iraq.

The rationale for more rapid FLOT movement becomes apparent when we examine the force ratios and surviving Tactical Equivalent Divisions (TED) as displayed in Figure D.2. In both cases, the force ratio begins at an arbitrary 20:1, indicating that the U.S. division is advanced unopposed to contact. When the battle is joined, the non-SFS methodology produces a force ratio of about 2:1, which continues until day 18 when the U.S. division finally achieves a breakthrough. By contrast, SFS generates a 6:1 force ratio on the second day of the battle, producing a rapid success for the U.S. forces. A comparison of surviving TED for the two forces shows even more dramatic differences. After the initial contact, non-SFS scoring produces gradual declines in TED for both forces. By contrast, SFS scoring causes catastrophic loss for the Iraqi forces and large fluctuations for the U.S. division, depending upon the situation.

The types of battle and time spent in various types of terrain are also markedly different in the two cases. Non-SFS scoring generates a protracted period of deliberate defense until the U.S. armored division with supporting F-16C wing causes enough attrition

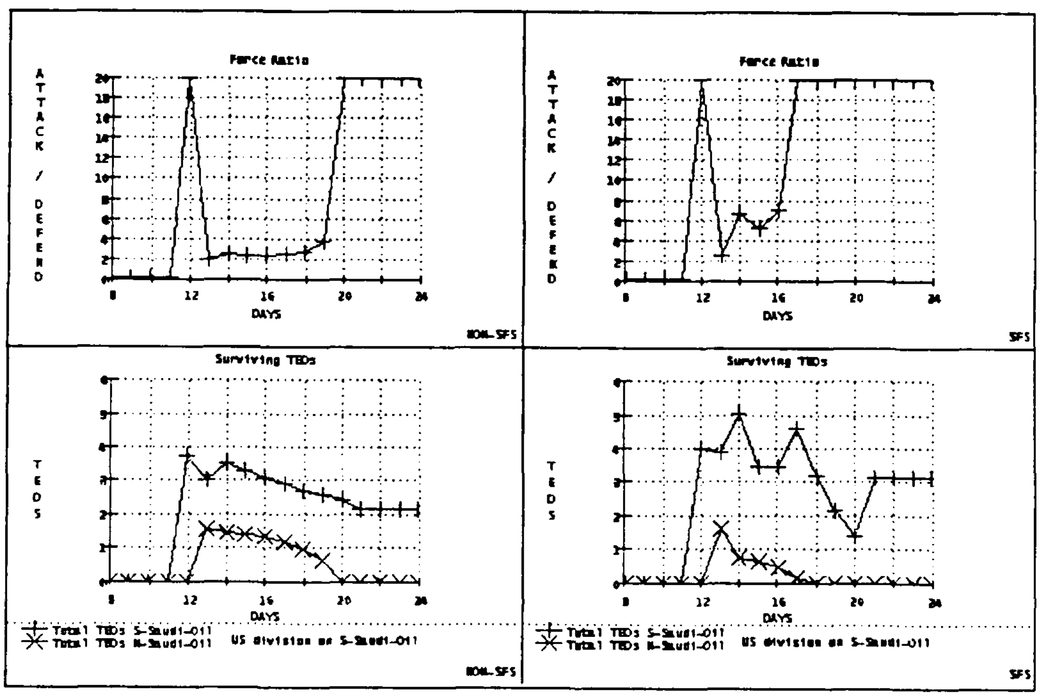

Fig. D.2—Force Ratio and Surviving Tactical Equivalent Divisions

to break through the defense. SFS scoring produces only one day of deliberate defense before moving to breakthrough and pursuit battles. In non-SFS adjudication, the U.S. division stays mired in the marshy terrain of the Tigris-Euphrates until the end of the simulation. In SFS adjudication, the U.S. division exits the marsh by day 19. Figure D.3 displays types of battle and terrain in the two cases.

The underlying cause for these observed differences becomes apparent when we examine the force mixes on each side. The U.S. division, when reinforced with corps artillery, is a well-balanced combined arms force. The Iraqi corps is infantry heavy and weak in the other arms. Its assigned armor has less than half the effectiveness of the armor contained in the U.S. division. Its artillery is numerous but inadequate in counterbattery capability. Adjudication based on non-SFS does not penalize the Iraqi corps for these deficiencies, while adjudication based on SFS penalizes it heavily. Non-SFS adjudication considers only the relative strengths in ED as adjusted to the tactical situation and generates monotonous grinding battles. SFS adjudication examines the force mixes. It assesses Iraqi shortages in armor and anti-artillery (counterbattery) capability. These shortages produce a corresponding gain in U.S. capability and provide the precondition for a breakthrough. SFS adjudication next recalculates on the basis of a breakthrough battle, producing the 6:1 force ratio previously observed.

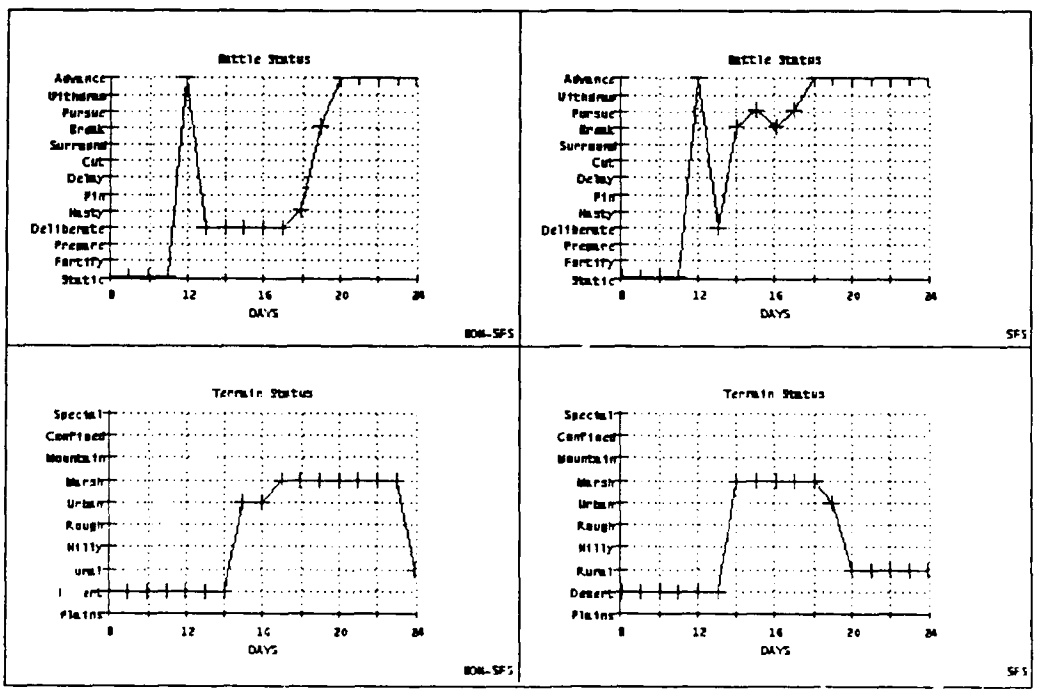

Fig. D.3—Type of Battle and Terrain

Figure D.4 shows the surviving armor and infantry for both sides. Using non-SFS, U.S. armor suffers the cumulative attrition associated with repeated assaults on defensive positions. Using SFS, U.S. armor sustains losses during several days of assault operations and thereafter suffers relatively little attrition. On the Iraqi side, there are substantial differences in the attrition suffered by infantry, the primary defending arm. Using non-SFS, Iraqi infantry (represented by the upper, cross-hatched graph line) experiences a protracted linear decline. Using SFS, the decline is extremely steep during the breakthrough battles.

As a result of differences in the ground war, the proportion of losses due to ground combat versus offensive air support (OAS) shifts in the two cases. Figure D.5 displays the cumulative attrition by cause. Using non-SFS, the attrition caused to the U.S. division by ground combat is more than twice the total when SFS is used. A more interesting difference is apparent when we examine attrition to Iraqi ground forces. In non-SFS, ground combat and OAS cause roughly similar attrition. In SFS, attrition due to ground combat versus attrition due to OAS diverge sharply towards the end of the assault operations. In other words, the non-SFS adjudication depicts attrition battles with ground forces and tactical air forces making approximately the same contribution. SFS adjudication depicts battles of breakthrough and pursuit that end when ground forces overwhelm their opponents.

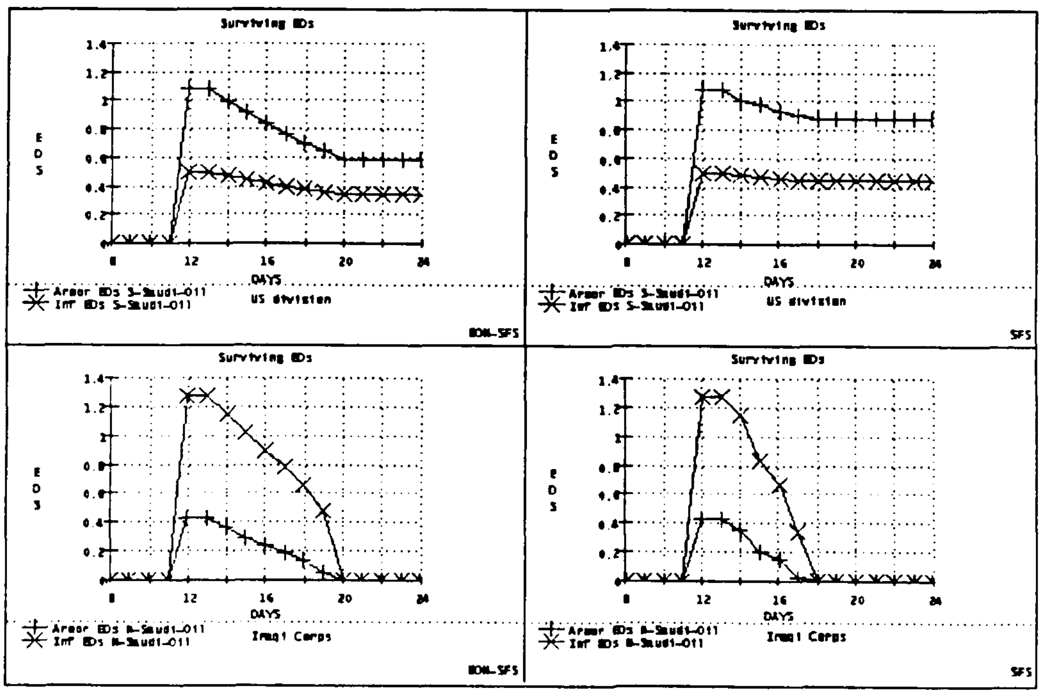

Fig. D.4—Surviving Armor and Infantry

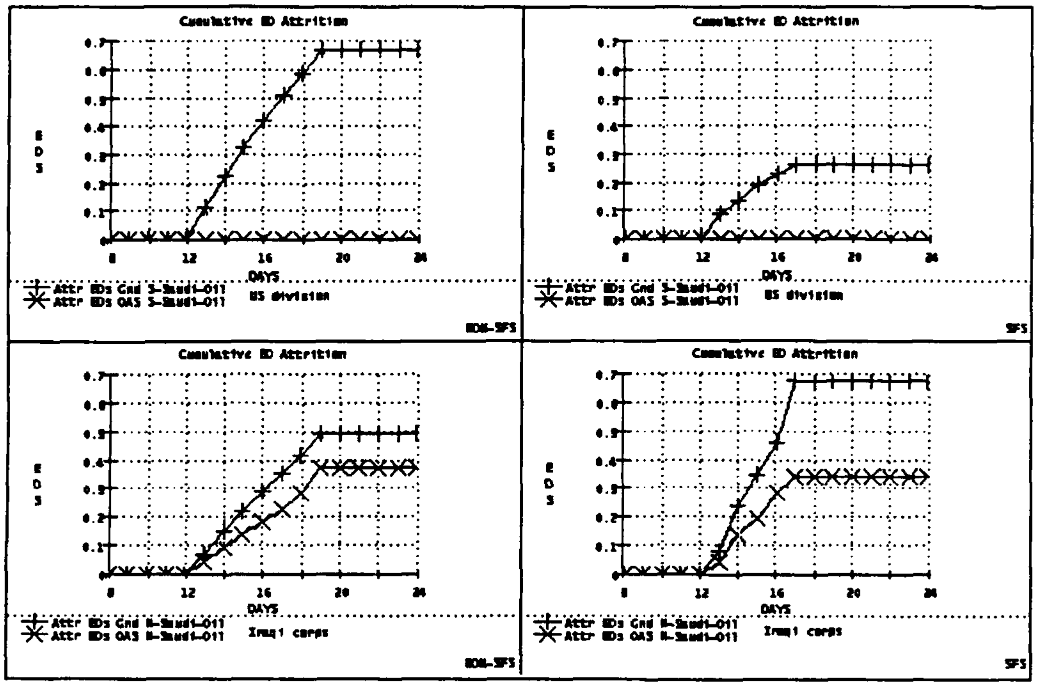

Fig. D.5—Cumulative Attrition Due to Ground Combat and OAS

This simple example suggests that adjudication using SFS generates outcomes that are richer and more realistic than those generated by comparable adjudication using non-SFS. The cost for greater realism is greater complexity and possibly some loss of transparency until a user becomes familiar with the SFS calculations described in Appendix F.

Appendix E
A NEW RSAS GROUND FORCE SCORING SYSTEM

RAND is pursuing the definition of a new ground force scoring system to replace the WEI/WUV system currently used in the RSAS.[1] While WEI/WUVs are the only scoring system with relative broad (though reluctant) acceptance in the community, neither RAND nor the RSAS users have been happy with the WEI/WUVs scores for a variety of reasons. RAND's alternative approach involves several major elements:

- A system that explicitly integrates force ratio adjudications with killer-victim scoreboard adjudications.
- A small set of weapon groups (the 13 discussed in the text) for recording ground force data and doing "reduced" scoreboard calculations.
- A set of weapon categories within each weapon group. Each category should include weapons that are qualitatively about 30 percent or so different from weapons in other categories within the group, and yet are sufficiently homogeneous that each weapon within the category can use the same score.
- A series of qualitative factors that can be reflected as multipliers and through other score adjustments.

From the perspective of the scoring system, the situation force scoring methodology represents a series of qualitative multipliers and other adjustments. In order to use the situational force scoring with the proposed scoring system, the same baseline has been chosen: both systems assume a defender in a deliberate defense in mixed terrain as the baseline.

Table E.1 shows a second cut at the proposed weapon groups and categories, and the score that would be applied for each. Table E.2 shows the groups and categories sorted by score for comparison purposes.

Because this new system is still being developed, RAND encourages comments and recommendations.

[1]This weapon scoring system is described in more detail in unpublished RAND work written by Bruce Bennett.

Table E.1

Proposed Scores by Weapon Group and Category

Group	Category	Score	Group	Category	Score
Tanks	M1-A1	7.5	SP Arty	152+ Hw Good	5.0
Tanks	M1	5.5	SP Arty	152+ Hw Fair	4.0
Tanks	M60-A3	3.5	SP Arty	SP Gun	3.5
Tanks	M60	2.5	SP Arty	122- Hw	2.7
Tanks	M48	1.8	SP Arty	100+ Mortar	1.5
Tanks	M47	1.4	SP Arty	MLRS	10.0
Tanks	T34	1.0	SP Arty	200+ mm MRL	7.5
IFV/AA	M-2	3.5	SP Arty	160- mm MRL Good	5.0
IFV/AA	BMP-1	2.5	SP Arty	160- mm MRL Fair	3.0
ARV/AA	ITV	2.5	Td Arty	122+ mm Gn/How	3.0
ARV/AA	ATGM	1.8	Td Arty	152+ mm How	2.7
ARV/AA	Gun/Armor	1.3	Td Arty	130+ mm Gun	2.5
ARV/AA	Gun/Lgt	1.0	Td Arty	122-130 mm How	1.8
ARV/AA	Lgt Tank	1.5	Td Arty	105- mm How	1.2
LARV	Lgt Veh	0.8	Td Arty	122- mm Gun	1.5
APC	IFV/No AT	1.3	Td Arty	100+ mm Mortar	1.0
APC	APC	1.0	Td Arty	107+ mm MRL	2.5
APC	Half Trk	0.8	At Hel	AH-64	10.0
LRAArm	Imp TOW/Veh	1.5	At Hel	Hind	6.5
LRAArm	TOW/Mln-Veh	1.2	At Hel	AH-1	3.5
LRAArm	Imp Tow/MP	1.2	At Hel	Lgt Attack	2.2
LRAArm	Tow/Mln-MP	0.9	ADef	20+ mm Rad ADA	1.5
LRAArm	Aslt/ATGN Hvy	1.2	ADef	57+ mm ADA	1.0
LRAArm	Aslt/ATGN Lgt	0.8	ADef	20+ mm SP ADA	1.0
SRAArm	Lrg Recoil	1.0	ADef	20-40 mm Td ADA	0.7
SRAArm	Sml Recoil	0.7	ADef	AAMG	0.4
SRAArm	Dragon	0.5	ADef	SA-13	2.5
SRAArm	LAWs	0.25	ADef	SA-8	1.8
SRAArm	Sml LAWs	0.2	ADef	Stinger	1.3
Mortar	SP 81 mm	1.2	ADef	SA-14	0.9
Mortar	81 mm	0.7	ADef	SA-7	0.5
Mortar	60 mm	0.4			
SmArm	Small Arms	0.15			

Table E.2

Proposed Scores Ranked by Weapon Score

Group	Category	Score	Group	Category	Score
At Hel	AH-64	10.0	Tanks	M47	1.4
SP Arty	MLRS	10.0	ADef	Stinger	1.3
SP Arty	200+ mm MRL	7.5	APC	IFV/No AT	1.3
Tanks	M1-A1	7.5	ARV/AA	Gun/Armor	1.3
At Hel	Hind	6.5	LRAArm	Aslt/ATGN Hvy	1.2
Tanks	M1	5.5	LRAArm	Imp Tow/MP	1.2
SP Arty	152+ Hw Good	5.0	LRAArm	TOW/Mln-Veh	1.2
SP Arty	160- mm MRL Good	5.0	Mortar	SP 81 mm	1.2
SP Arty	152+ Hw Fair	4.0	Td Arty	105- mm How	1.2
At Hel	AH-1	3.5	ADef	20+ mm SP ADA	1.0
IFV/AA	M-2	3.5	ADef	57+ mm ADA	1.0
SP Arty	SP Gun	3.5	APC	APC	1.0
Tanks	M60-A3	3.5	ARV/AA	Gun/Lgt	1.0
SP Arty	160- mm MRL Fair	3.0	SRAArm	Lrg Recoil	1.0
Td Arty	122+ mm Gn/How	3.0	Tanks	T34	1.0
SP Arty	122- Hw	2.7	Td Arty	100+ mm Mortar	1.0
Td Arty	152+ mm How	2.7	ADef	SA-14	0.9
ADef	SA-13	2.5	LRAArm	Tow/Mln-MP	0.9
ARV/AA	ITV	2.5	APC	Half Trk	0.8
IFV/AA	BMP-1	2.5	LARV	Lgt Veh	0.8
Tanks	M60	2.5	LRAArm	Aslt/ATGN Lgt	0.8
Td Arty	107+ mm MRL	2.5	ADef	20-40 mm Td ADA	0.7
Td Arty	130+ mm Gun	2.5	Mortar	81 mm	0.7
At Hel	Lgt Attack	2.2	SRAArm	Sml Recoil	0.7
ADef	SA-8	1.8	ADef	SA-7	0.5
ARV/AA	ATGM	1.8	SRAArm	Dragon	0.5
Tanks	M48	1.8	ADef	AAMG	0.4
Td Arty	122-130 mm How	1.8	Mortar	60 mm	0.4
ADef	20+ mm Rad ADA	1.5	SRAArm	LAWs	0.25
ARV/AA	Lgt Tank	1.5	SRAArm	Sml LAWs	0.2
LRAArm	Imp TOW/Veh	1.5	SmArm	Small Arms	0.15
SP Arty	100+ Mortar	1.5			
Td Arty	122- mm Gun	1.5			

Appendix F
SAMPLE SFS CALCULATIONS

As indicated in the text, the SFS methodology has been implemented in the RSAS CAMPAIGN-ALT model as described herein. To illustrate this methodology, we have run four examples in CAMPAIGN-ALT that illustrate the impact of the SFS methodology. In each, a U.S. armored division attacks two U.S. Light Infantry Divisions (LIDs). The first example has the attack occur "in the plains," the CAMPAIGN-ALT terminology for "open" terrain. As might be expected, the armored division easily breaks through the LIDs, overrunning their infantry elements. The second example has the attack occur in the mountains; in this case, the armored division is unable to pursue the attack and must settle for a stalemate type of battle (changing this attack to a main attack—as opposed to the default of a supporting attack—might press the armored division to attack, though clearly in very unfavorable circumstances).

The third and fourth examples are the same as the first two examples, except that the two defending light infantry divisions include attack helicopters. In these examples, we have not accounted for the attrition caused by the attack helicopters, but just the contribution of the attack helicopters to the combined arms capabilities of the defending force. Note that due to the presence of the attack helicopters, some of the shortages (and therefore the shortage effects) assessed against the defending force have been reduced. For example, the attack helicopters provide some compensation for the armor, artillery, anti-armor, antisoft, and anti-artillery shortages. These effects are sufficient to completely remove the shortage of artillery platforms in the open terrain case. Even with helicopter support, however, the two light infantry divisions still get overrun by the armored division in open terrain, as would be expected.

In each example, an initial assessment is done in a deliberate defense mode in order to determine whether or not the deliberate mode is the appropriate type of battle. In the first and third examples, the SFS force ratio is so high that a breakthrough is adjudicated (in contrast, CAMPAIGN-MT uses force density, as opposed to force ratio, to adjudicate breakthroughs). In the second and fourth examples, the armored division has insufficient force ratio for an attack on a deliberate defense (given the basic rules in CAMPAIGN-ALT), and so the type of battle transitions to a stalemate.

We should note the additional attrition against the defending forces caused by the "overrun" combat result. When the breakthrough was assessed in the first and third cases, the relative movement rates of the attacking and defending forces were compared. Since the defending force could not move as quickly as the attacking force, the defending force was assessed to be overrun. A severe additional attrition penalty (149 percent) was assessed against the defending force. Due to these significant losses, the two overrun units broke and became combat ineffective.

As a final note, the repair rates of the attacking and defending units are assessed as a function of the FLOT movement rate. When the FLOT is stationary, then each side can recover and repair damaged assets, primarily armor and artillery. (We do not currently have a medical subroutine included in the model.) When the FLOT is moving quickly in favor of the attacker, the attacker may still recover a significant fraction of his damaged assets. When the FLOT is moving quickly against the defender, however, the defender will have little opportunity to recover and repair his damaged assets. As the FLOT moves faster, less of the damaged assets can be recovered and repaired. In the first and third examples, none of the defending assets could be recovered and repaired since both of the units were overrun. Even in cases where the defending force was not overrun, the faster the FLOT movement rate, the smaller the fraction of assets that can be recovered and repaired by the defender.

Example 1: A U.S. Armored Division Attacking Two LIDs Without Helicopters in the Plains

```
1 ARMD attacks 2 LIDs in Plains
------------------------------

         ATTACK Axis-1                       | DEFEND Axis-1

ASSETS   armor inf   arty                    | armor inf   arty
         ----- ----- -----                   | ----- ----- -----
Totl Eq   1092  2254   159                   |     0  8620   124
Max  Eq   1800  7875  2000                   |  1800  7875  2000
Tot/Max    61%   29%    8%                   |    0%  109%    6%
Kms used  22.5  22.5  25.0                   |  22.5  22.5  25.0

SIT EDS  tank mech veh  atgm inf  arty totl| tank mech veh  atgm inf arty totl
         ---- ---- ---- ---- ---- ---- ----| ---- ---- ---- ---- --- ---- ----
Totl ED  0.40 0.30 0.07 0.04 0.06 0.13 1.00| 0.00 0.00 0.00 0.06 0.32 0.11 0.49
Enga ED  0.40 0.30 0.07 0.04 0.06 0.13 1.00| 0.00 0.00 0.00 0.05 0.29 0.11 0.46
Eff   X            1.00                    |                1.00
Enga EED 0.40 0.30 0.07 0.04 0.06 0.13 1.00| 0.00 0.00 0.00 0.05 0.29 0.11 0.46

Plains X 1.15 1.15 1.15 0.90 0.90 1.10     | 1.10 1.10 1.10 0.90 0.90 1.10
Delib- X 1.00 1.00 0.70 0.90 0.80 1.00     | 1.00 1.00 0.70 1.00 1.00 1.00
Total X  1.15 1.15 0.80 0.81 0.72 1.10     | 1.10 1.10 0.77 0.90 0.90 1.10
Sit ED   0.46 0.34 0.06 0.03 0.04 0.14 1.08| 0.00 0.00 0.00 0.05 0.26 0.12 0.43

SHORTAGES               anti anti anti     |                anti anti anti
         armr inf  arty armr inf  arty     | armr inf  arty armr inf  arty
         ---- ---- ---- ---- ---- ----     | ---- ---- ---- ---- ---- ----
Capacity 0.86 0.08 0.14 0.81 0.71 0.10     | 0.00 0.31 0.12 0.09 0.39 0.08
         ----Density--- ----Ratio-----     | ----Density--- ----Ratio-----
Current  .038 .003 .006 9.99 2.27 0.83     | .000 .014 .005 0.11 5.11 0.59
Required .025 .003 .008 2.00 2.00 0.50     | .015 .002 .005 0.50 1.00 0.20
Short?     No   No  Yes   No   No   No     |  Yes   No  Yes  Yes   No   No
Fraction           0.71                    | 0.00      0.97 0.21

TAC EDS  tank mech veh  atgm inf  arty totl| tank mech veh  atgm inf  arty totl
         ---- ---- ---- ---- ---- ---- ----| ---- ---- ---- ---- ---- ---- ----
Sit EDs  0.46 0.34 0.06 0.03 0.04 0.14     | 0.00 0.00 0.00 0.05 0.26 0.12
Short  X 0.76 0.76 0.76 0.76 0.76 1.00     | 0.97 0.97 0.97 0.28 0.28 1.00
  anti X 2.29 2.29 2.29 1.00 1.00 1.00     | 1.00 1.00 1.00 1.00 1.00 1.00
Tac EDs  0.80 0.60 0.10 0.02 0.03 0.14 1.71| 0.00 0.00 0.00 0.01 0.07 0.12 0.21

 8.20 force ratio leads to breakthru
```

Example 1—continued

```
        ATTACK Axis-1                               | DEFEND Axis-1

ASSETS  armor inf   arty                            |  armor inf   arty
        ----- ----- -----                           |  ----- ----- -----
Totl Eq   1092  2254   159                          |      0  8620   124
Max  Eq   1800  7875  2000                          |   1800  7875  2000
Tot/Max    61%   29%    8%                          |     0%  109%    6%
Kms used  22.5  22.5  25.0                          |   22.5  22.5  25.0

SIT EDS  tank mech veh  atgm inf  arty totl| tank mech veh  atgm inf  arty totl
         ---- ---- ---- ---- ---- ---- ----| ---- ---- ---- ---- ---- ---- ----
Totl ED  0.40 0.30 0.07 0.04 0.06 0.13 1.00| 0.00 0.00 0.00 0.06 0.32 0.11 0.49
Enga ED  0.40 0.30 0.07 0.04 0.06 0.13 1.00| 0.00 0.00 0.00 0.05 0.29 0.11 0.46
Eff  X             1.00                    |                1.00
Enga EED 0.40 0.30 0.07 0.04 0.06 0.13 1.00| 0.00 0.00 0.00 0.05 0.29 0.11 0.46

Plains X 1.15 1.15 1.15 0.90 0.90 1.10     | 1.10 1.10 1.10 0.90 0.90 1.10
Breakt X 1.40 1.40 1.82 0.36 0.32 0.40     | 0.80 0.80 1.04 0.50 0.50 0.50
Total X  1.61 1.61 2.09 0.32 0.29 0.44     | 0.88 0.88 1.14 0.45 0.45 0.55
Sit ED   0.64 0.48 0.15 0.01 0.02 0.(  ..36| 0.00 0.00 0.00 0.02 0.13 0.06 0.22

SHORTAGES               anti anti          |                anti anti anti
         armr inf  arty armr inf  arty     | armr inf  arty armr inf  arty
         ---- ---- ---- ---- ---- ----     | ---- ---- ---- ---- ---- ----
Capacity 1.27 0.03 0.06 1.07 0.83 0.34     | 0.00 0.16 0.06 0.05 0.19 0.04
         ----Density--- ----Ratio-----     | ----Density--- ----Ratio-----
Current  .057 .001 .002 9.99 5.30 5.60     | .000 .007 .002 0.04 6.39 0.74
Required .025 .001 .002 2.00 0.60 0.10     | .015 .000 .002 0.50 0.50 0.10
Short?     No   No   No   No   No   No     |  Yes   No   No  Yes   No   No
Fraction                                   | 0.00           0.07

TAC EDS  tank mech veh  atgm inf  arty totl| tank mech veh  atgm inf  arty totl
         ---- ---- ---- ---- ---- ---- ----| ---- ---- ---- ---- ---- ---- ----
Sit EDs  0.64 0.48 0.15 0.01 0.02 0.06     | 0.00 0.00 0.00 0.02 0.13 0.06
Short  X 1.00 1.00 1.00 1.00 1.00 1.00     | 1.00 1.00 1.00 0.29 0.29 1.00
  anti X 2.97 2.97 2.97 1.00 1.00 1.00     | 1.00 1.00 1.00 1.00 1.00 1.00
Tac EDs  1.91 1.43 0.44 0.01 0.02 0.06 3.87| 0.00 0.00 0.00 0.01 0.04 0.06 0.11

Loss   X 2.00 2.00 2.00 1.00 1.00 0.20     | 1.20 1.20 1.20 1.00 1.00 0.80
Short  X 0.34 0.34 0.34 1.00 1.00 1.00     | 1.00 1.00 1.00 3.50 3.50 1.00
ED loss  .007 .005 .001 .001 .002 .001 .017| .000 .000 .000 .028 .149 .013 .190

20.00 force ratio, 0.42 def loss rate, 0.82 exchange rate, 0.02 att loss rate
 Med intensity breakthru in plains terrain for 1.25 divs
 94.40 FLOT advance to 94.40 kms

Unit ARMD repairs at 0.30 rate, 100.00 max-move
Unit LID1 repairs at 0.00 rate, 20.00 max-move
Unit LID2 repairs at 0.00 rate, 20.00 max-move

Unit LID1 overrun at 94 FLOT advance vs. 20 max movement rate
     added 149% attrition to inf, 30% to armor/arty
Unit LID2 overrun at 94 FLOT advance vs. 20 max movement rate
     added 149% attrition to inf, 30% to armor/arty

Unit LID1 broken at 0.12 EDs (50% strength)
Unit LID2 broken at 0.12 EDs (50% strength)
```

Example 2: A U.S. Armored Division Attacking Two LIDs Without Helicopters in the Mountains

```
1 ARMD attacks 2 LIDs in Mountains
----------------------------------

         ATTACK Axis 1                          | DEFEND Axis 1

ASSETS   armor inf   arty                       |  armor inf   arty
         ----- ----- -----                      |  ----- ----- -----
Totl Eq   1092  2254   159                      |      0  8620   124
Max  Eq    400  5250   800                      |    400  5250   800
Tot/Max   273%   43%   20%                      |     0%  164%   16%
Kms used   5.0  15.0  10.0                      |    5.0  15.0  10.0

SIT EDS  tank mech veh  atgm inf  arty totl| tank mech veh  atgm inf  arty totl
         ---- ---- ---- ---- ---- ---- ----| ---- ---- ---- ---- ---- ---- ----
Totl ED  0.40 0.30 0.07 0.04 0.06 0.13 1.00| 0.00 0.00 0.00 0.06 0.32 0.11 0.49
Enga ED  0.15 0.11 0.03 0.04 0.06 0.13 0.51| 0.00 0.00 0.00 0.04 0.19 0.11 0.34
Eff   X             1.00                   |               1.00
Enga EED 0.15 0.11 0.03 0.04 0.06 0.13 0.51| 0.00 0.00 0.00 0.04 0.19 0.11 0.34

Mounta X 0.80 0.80 0.80 1.60 1.60 0.80     | 0.80 0.80 0.80 1.60 1.60 0.80
Delib- X 1.00 1.00 0.70 0.90 0.80 1.00     | 1.00 1.00 0.70 1.00 1.00 1.00
Total X  0.80 0.80 0.56 1.44 1.28 0.80     | 0.80 0.80 0.56 1.60 1.60 0.80
Sit ED   0.12 0.09 0.01 0.06 0.08 0.10 0.46| 0.00 0.00 0.00 0.06 0.31 0.09 0.46

SHORTAGES               anti anti anti     |                anti anti anti
         armr inf  arty armr inf  arty     | armr inf  arty armr inf  arty
         ---- ---- ---- ---- ---- ----     | ---- ---- ---- ---- ---- ----
Capacity 0.22 0.13 0.10 0.28 0.32 0.07     | 0.00 0.37 0.09 0.09 0.40 0.06
         ----Density--- ----Ratio-----     | ----Density--- ----Ratio-----
Current  .044 .009 .010 9.99 0.86 0.83     | .000 .025 .009 0.42 3.00 0.59
Required .000 .008 .004 1.00 2.00 0.50     | .000 .006 .002 0.30 1.00 0.20
Short?     No   No   No   No  Yes   No     |   No   No   No   No   No   No
Fraction                     0.43

TAC EDS  tank mech veh  atgm inf  arty totl| tank mech veh  atgm inf  arty totl
         ---- ---- ---- ---- ---- ---- ----| ---- ---- ---- ---- ---- ---- ----
Sit EDs  0.12 0.09 0.01 0.06 0.08 0.10     | 0.00 0.00 0.00 0.06 0.31 0.09
Short  X 1.00 1.00 1.00 1.00 1.00 1.00     | 1.00 1.00 1.00 1.00 1.00 1.00
  anti X 1.00 1.00 1.00 1.00 1.00 1.00     | 1.00 1.00 1.00 1.91 1.91 1.00
Tac EDs  0.12 0.09 0.01 0.06 0.08 0.10 0.46| 0.00 0.00 0.00 0.11 0.60 0.09 0.80

 0.58 force ratio leads to stalemate
```

Example 2—continued

```
        ATTACK Axis-1                             | DEFEND Axis-1

ASSETS   armor inf   arty                          |  armor inf   arty
         ----- ----- -----                         |  ----- ----- -----
Totl Eq   1092  2254   159                         |      0  8620   124
Max  Eq    400  5250   800                         |    400  5250   800
Tot/Max   273%   43%   20%                         |     0%  164%   16%
Kms used   5.0  15.0  10.0                         |    5.0  15.0  10.0

SIT EDS  tank mech veh  atgm inf  arty totl| tank mech veh  atgm inf  arty totl
         ---- ---- ---- ---- ---- ---- ----| ---- ---- ---- ---- ---- ---- ----
Totl ED  0.40 0.30 0.07 0.04 0.06 0.13 1.00| 0.00 0.00 0.00 0.06 0.32 0.11 0.49
Enga ED  0.15 0.11 0.03 0.04 0.06 0.13 0.51| 0.00 0.00 0.00 0.04 0.19 0.11 0.34
Eff  X              1.00                   |                1.00
Enga EED 0.15 0.11 0.03 0.04 0.06 0.13 0.51| 0.00 0.00 0.00 0.04 0.19 0.11 0.34

Mounta X 0.80 0.80 0.80 1.60 1.60 0.80     | 0.80 0.80 0.80 1.60 1.60 0.80
Stalem X 0.80 0.80 0.80 0.50 0.50 1.20     | 0.50 0.50 0.50 0.35 0.35 0.75
Total X  0.64 0.64 0.64 0.80 0.80 0.96     | 0.40 0.40 0.40 0.56 0.56 0.60
Sit ED   0.09 0.07 0.02 0.03 0.05 0.12 0.39| 0.00 0.00 0.00 0.02 0.11 0.07 0.20

SHORTAGES                anti anti anti    |                anti anti anti
         armr inf  arty armr inf  arty     | armr inf  arty armr inf  arty
         ---- ---- ---- ---- ---- ----     | ---- ---- ---- ---- ---- ----
Capacity 0.18 0.08 0.12 0.22 0.28 0.09     | 0.00 0.13 0.07 0.04 0.18 0.05
         ----Density--- ----Ratio-----     | ----Density--- ----Ratio-----
Current  .036 .005 .012 9.99 2.18 1.32     | .000 .009 .007 0.24 2.20 0.37
Required .000 .004 .002 1.00 1.00 0.25     | .000 .003 .001 0.30 1.00 0.20
Short?     No   No   No   No   No   No     |   No   No   No  Yes   No   No
Fraction                                                    0.78

TAC EDS  tank mech veh  atgm inf  arty totl| tank mech veh  atgm inf  arty totl
         ---- ---- ---- ---- ---- ---- ----| ---- ---- ---- ---- ---- ---- ----
Sit EDs  0.09 0.07 0.02 0.03 0.05 0.12     | 0.00 0.00 0.00 0.02 0.11 0.07
Short  X 1.00 1.00 1.00 1.00 1.00 1.00     | 1.00 1.00 1.00 1.00 1.00 1.00
  anti X 1.14 1.14 1.14 1.00 1.00 1.00     | 1.00 1.00 1.00 1.00 1.00 1.00
Tac EDs  0.11 0.08 0.02 0.03 0.05 0.12 0.41| 0.00 0.00 0.00 0.02 0.11 0.07 0.20

Loss  X  1.50 1.50 1.50 1.00 1.00 2.00     | 1.50 1.50 1.50 1.00 1.00 2.00
Short X  0.88 0.88 0.88 1.00 1.00 1.00     | 1.00 1.00 1.00 1.00 1.00 1.00
ED loss  .001 .001 .000 .000 .000 .001 .004| .000 .000 .000 .000 .002 .002 .004

2.10 force ratio, 0.01 def loss rate, 2.18 exchange rate, 0.01 att loss rate
 Med intensity stalemate in mountain terrain for 1.25 divs
 0.00 FLOT advance to 0.00 kms


Unit ARMD repairs at 0.30 rate, 20.00 max-move
Unit LID1 repairs at 0.30 rate, 20.00 max-move
Unit LID2 repairs at 0.30 rate, 20.00 max-move
```

Example 3: A U.S. Armored Division Attacking Two LIDs with Helicopters in the Plains

```
1 ARMD attacks 2 LIDs in Plains
------------------------------

        ATTACK Axis-1                             | DEFEND Axis-1

ASSETS   armor inf   arty                         | armor inf   arty
         ----- ----- -----                        | ----- ----- -----
Totl Eq   1092  2254   159                        |     0  8620   124
Max  Eq   1800  7875  2000                        |  1800  7875  2000
Tot/Max    61%   29%    8%                        |    0%  109%    6%
Kms used  22.5  22.5  25.0                        |  22.5  22.5  25.0

SIT EDS  tank mech veh  atgm inf  arty totl| tank mech veh  atgm inf arty totl
         ---- ---- ---- ---- ---- ---- ----| ---- ---- ---- ---- --- ---- ----
Totl ED  0.40 0.30 0.07 0.04 0.06 0.13 1.00| 0.00 0.00 0.00 0.06 0.32 0.11 0.49
Enga ED  0.40 0.30 0.07 0.04 0.06 0.13 1.00| 0.00 0.00 0.00 0.05 0.29 0.11 0.46
Eff   X             1.00                   |                1.00
Enga EED 0.40 0.30 0.07 0.04 0.06 0.13 1.00| 0.00 0.00 0.00 0.05 0.29 0.11 0.46

Plains X 1.15 1.15 1.15 0.90 0.90 1.10     | 1.10 1.10 1.10 0.90 0.90 1.10
Delib- X 1.00 1.00 0.70 0.90 0.80 1.00     | 1.00 1.00 0.70 1.00 1.00 1.00
Total X  1.15 1.15 0.80 0.81 0.72 1.10     | 1.10 1.10 0.77 0.90 0.90 1.10
Sit ED   0.46 0.34 0.06 0.03 0.04 0.14 1.08| 0.00 0.00 0.00 0.05 0.26 0.12 0.43

SHORTAGES                anti anti anti    |                anti anti anti
         armr inf  arty armr inf  arty     | armr inf  arty armr inf  arty
         ---- ---- ---- ---- ---- ----     | ---- ---- ---- ---- ---- ----
Capacity 0.86 0.08 0.14 0.81 0.71 0.10     | 0.01 0.31 0.14 0.12 0.41 0.10
         ----Density--- ----Ratio-----     | ----Density--- ----Ratio-----
Current  .038 .003 .006 64.8 2.27 0.70     | .001 .014 .006 0.14 5.39 0.71
Required .025 .003 .008 2.00 2.00 0.50     | .015 .002 .005 0.50 1.00 0.20
Short?     No   No  Yes   No   No   No     |  Yes   No   No  Yes   No   No
Fraction           0.71                    | 0.04           0.29

TAC EDS  tank mech veh  atgm inf  arty totl| tank mech veh  atgm inf  arty totl
         ---- ---- ---- ---- ---- ---- ----| ---- ---- ---- ---- ---- ---- ----
Sit EDs  0.46 0.34 0.06 0.03 0.04 0.14     | 0.00 0.00 0.00 0.05 0.26 0.12
Short  X 0.76 0.76 0.76 0.76 0.76 1.00     | 1.00 1.00 1.00 0.31 0.31 1.00
  anti X 2.03 2.03 2.03 1.00 1.00 1.00     | 1.00 1.00 1 00 1.00 1.00 1.00
Tac EDs  0.71 0.53 0.09 0.02 0.03 0.14 1.54| 0.00 0.00 0.00 0.02 0.08 0.12 0.22

 7.02 force ratio leads to breakthrough
```

Example 3—continued

```
          ATTACK Axis-1                          | DEFEND Axis-1

ASSETS    armor inf   arty                       |  armor inf   arty
          ----- ----- -----                      |  ----- ----- -----
Totl Eq    1092  2254   159                      |      0  8620   124
Max  Eq    1800  7875  2000                      |   1800  7875  2000
Tot/Max     61%   29%    8%                      |     0%  109%    6%
Kms used   22.5  22.5  25.0                      |   22.5  22.5  25.0

SIT EDS   tank mech veh  atgm inf  arty totl| tank mech veh  atgm inf  arty totl
          ---- ---- ---- ---- ---- ---- ----| ---- ---- ---- ---- ---- ---- ----
Totl ED   0.40 0.30 0.07 0.04 0.06 0.13 1.00| 0.00 0.00 0.00 0.06 0.32 0.11 0.49
Enga ED   0.40 0.30 0.07 0.04 0.06 0.13 1.00| 0.00 0.00 0.00 0.05 0.29 0.11 0.46
Eff  X                1.00                  |                1.00
Enga EED  0.40 0.30 0.07 0.04 0.06 0.13 1.00| 0.00 0.00 0.00 0.05 0.29 0.11 0.46

Plains X  1.15 1.15 1.15 0.90 0.90 1.10     | 1.10 1.10 1.10 0.90 0.90 1.10
Breakt X  1.40 1.40 1.82 0.36 0.32 0.40     | 0.80 0.80 1.04 0.50 0.50 0.50
Total X   1.61 1.61 2.09 0.32 0.29 0.44     | 0.88 0.88 1.14 0.45 0.45 0.55
Sit ED    0.64 0.48 0.15 0.01 0.02 0.06 1.36| 0.00 0.00 0.00 0.02 0.13 0.06 0.22

SHORTAGES                anti anti anti     |                anti anti anti
          armr inf  arty armr inf  arty     | armr inf  arty armr inf  arty
          ---- ---- ---- ---- ---- ----     | ---- ---- ---- ---- ---- ----
Capacity  1.27 0.03 0.06 1.07 0.83 0.34     | 0.00 0.16 0.08 0.08 0.21 0.06
          ----Density--- ----Ratio-----     | ----Density--- ----Ratio-----
Current   .057 .001 .002 84.8 5.30 4.16     | .001 .007 .003 0.06 7.09 1.11
Required  .025 .001 .002 2.00 0.60 0.10     | .015 .000 .002 0.50 0.50 0.10
Short?      No   No   No   No   No   No     |  Yes   No   No  Yes   No   No
Fraction                                    | 0.04           0.12

TAC EDS   tank mech veh  atgm inf  arty totl| tank mech veh  atgm inf  arty totl
          ---- ---- ---- ---- ---- ---- ----| ---- ---- ---- ---- ---- ---- ----
Sit EDs   0.64 0.48 0.15 0.01 0.02 0.06     | 0.00 0.00 0.00 0.02 0.13 0.06
Short  X  1.00 1.00 1.00 1.00 1.00 1.00     | 1.00 1.00 1.00 0.31 0.31 1.00
  anti X  2.67 2.67 2.67 1.00 1.00 1.00     | 1.00 1.00 1.00 1.00 1.00 1.00
Tac EDs   1.72 1.29 0.39 0.01 0.02 0.06 3.49| 0.00 0.00 0.00 0.01 0.04 0.06 0.11

Loss  X   2.00 2.00 2.00 1.00 1.00 0.20     | 1.20 1.20 1.20 1.00 1.00 0.80
Short X   0.37 0.37 0.37 1.00 1.00 1.00     | 1.00 1.00 1.00 3.20 3.20 1.00
ED loss   .007 .005 .001 .001 .001 .001 .017| .000 .000 .000 .028 .148 .014 .190

20.00 force ratio, 0.42 def loss rate, 0.82 exchange rate, 0.02 att loss rate
 Med intensity breakthru in plains terrain for 1.25 divs
 94.40 FLOT advance to 94.40 kms

Unit ARMD repairs at 0.30 rate, 94.00 max-move
Unit LID1 repairs at 0.00 rate, 20.00 max-move
Unit LID2 repairs at 0.00 rate, 20.00 max-move

Unit LID1 overrun at 94 FLOT advance vs. 20 max movement rate
     added 149% attrition to inf, 32% to armor/arty
Unit LID2 overrun at 94 FLOT advance vs. 20 max movement rate
     added 149% attrition to inf, 32% to armor/arty

Unit LID1 broken at 0.12 EDs (50% strength)
Unit LID2 broken at 0.12 EDs (50% strength)
```

Example 4: A U.S. Armored Division Attacking Two LIDs with Helicopters in the Mountains

```
1 ARMD attacks 2 LIDs in Mountains
----------------------------------

         ATTACK Axis-1                          | DEFEND Axis-1

ASSETS   armor inf   arty                       |  armor inf   arty
         ----- ----- -----                      |  ----- ----- -----
Totl Eq   1092  2254   159                      |      0  8620   124
Max  Eq    400  5250   800                      |    400  5250   800
Tot/Max   273%   43%   20%                      |     0%  164%   16%
Kms used   5.0  15.0  10.0                      |    5.0  15.0  10.0

SIT EDS  tank mech veh  atgm inf  arty totl| tank mech veh  atgm inf  arty totl
         ---- ---- ---- ---- ---- ---- ----| ---- ---- ---- ---- ---- ---- ----
Totl ED  0.40 0.30 0.07 0.04 0.06 0.13 1.00| 0.00 0.00 0.00 0.06 0.32 0.11 0.49
Enga ED  0.15 0.11 0.03 0.04 0.06 0.13 0.51| 0.00 0.00 0.00 0.04 0.19 0.11 0.34
Eff   X            1.00                    |               1.00
Enga EED 0.15 0.11 0.03 0.04 0.06 0.13 0.51| 0.00 0.00 0.00 0.04 0.19 0.11 0.34

Mounta X 0.80 0.80 0.80 1.60 1.60 0.80     | 0.80 0.80 0.80 1.60 1.60 0.80
Delib- X 1.00 1.00 0.70 0.90 0.80 1.00     | 1.00 1.00 0.70 1.00 1.00 1.00
Total X  0.80 0.80 0.56 1.44 1.28 0.80     | 0.80 0.80 0.56 1.60 1.60 0.80
Sit ED   0.12 0.09 0.01 0.06 0.08 0.10 0.46| 0.00 0.00 0.00 0.06 0.31 0.09 0.46

SHORTAGES                anti anti anti     |                anti anti anti
         armr inf  arty armr inf  arty     | armr inf  arty armr inf  arty
         ---- ---- ---- ---- ---- ----     | ---- ---- ---- ---- ---- ----
Capacity 0.22 0.13 0.10 0.28 0.32 0.07     | 0.01 0.37 0.11 0.12 0.42 0.08
         ----Density--- ----Ratio-----     | ----Density--- ----Ratio-----
Current  .044 .009 .010 22.1 0.86 0.67     | .003 .025 .011 0.57 3.15 0.75
Required .000 .008 .004 1.00 2.00 0.50     | .000 .006 .002 0.30 1.00 0.20
Short?     No   No   No   No  Yes   No     |   No   No   No   No   No   No
Fraction                     0.43

TAC EDS  tank mech veh  atgm inf  arty totl| tank mech veh  atgm inf  arty totl
         ---- ---- ---- ---- ---- ---- ----| ---- ---- ---- ---- ---- ---- ----
Sit EDs  0.12 0.09 0.01 0.06 0.08 0.10     | 0.00 0.00 0.00 0.06 0.31 0.09
Short  X 1.00 1.00 1.00 1.00 1.00 1.00     | 1.00 1.00 1.00 1.00 1.00 1.00
  anti X 1.00 1.00 1.00 1.00 1.00 1.00     | 1.00 1.00 1.00 1.91 1.91 1.00
Tac EDs  0.12 0.09 0.01 0.06 0.08 0.10 0.46| 0.00 0.00 0.00 0.11 0.60 0.09 0.80

 0.58 force ratio leads to stalemate
```

Example 4—continued

```
         ATTACK Axis-1                           | DEFEND Axis-1

ASSETS   armor inf   arty                        |  armor inf   arty
         ----- ----- -----                       |  ----- ----- -----
Totl Eq   1092  2254   159                       |      0  8620   124
Max  Eq    400  5250   800                       |    400  5250   800
Tot/Max   273%   43%   20%                       |     0%  164%   16%
Kms used   5.0  15.0  10.0                       |    5.0  15.0  10.0

SIT EDS  tank mech veh  atgm inf  arty totl| tank mech veh  atgm inf  arty totl
         ---- ---- ---- ---- ---- ---- ----| ---- ---- ---- ---- ---- ---- ----
Totl ED  0.40 0.30 0.07 0.04 0.06 0.13 1.00| 0.00 0.00 0.00 0.06 0.32 0.11 0.49
Enga ED  0.15 0.11 0.03 0.04 0.06 0.13 0.51| 0.00 0.00 0.00 0.04 0.19 0.11 0.34
Eff   X                1.00                |                1.00
Enga EED 0.15 0.11 0.03 0.04 0.06 0.13 0.51| 0.00 0.00 0.00 0.04 0.19 0.11 0.34

Mounta X 0.80 0.80 0.80 1.60 1.60 0.80     | 0.80 0.80 0.80 1.60 1.60 0.80
Stalem X 0.80 0.80 0.80 0.50 0.50 1.20     | 0.50 0.50 0.50 0.35 0.35 0.75
Total X  0.64 0.64 0.64 0.80 0.80 0.96     | 0.40 0.40 0.40 0.56 0.56 0.60
Sit ED   0.09 0.07 0.02 0.03 0.05 0.12 0.39| 0.00 0.00 0.00 0.02 0.11 0.07 0.20

SHORTAGES               anti anti anti     |                anti anti anti
         armr inf  arty armr inf  arty     | armr inf  arty armr inf  arty
         ---- ---- ---- ---- ---- ----     | ---- ---- ---- ---- ---- ----
Capacity 0.18 0.08 0.22 0.22 0.28 0.09     | 0.01 0.13 0.09 0.08 0.20 0.06
         ----Density--- ----Ratio-----     | ----Density--- ----Ratio-----
Current  .036 .005 .012 17.6 2.18 1.00     | .003 .009 .009 0.42 2.46 0.50
Required .000 .004 .002 1.00 1.00 0.25     | .000 .003 .001 0.30 1.00 0.20
Short?     No   No   No   No   No   No     |   No   No   No   No   No   No
Fraction

TAC EDS  tank mech veh  atgm inf  arty totl| tank mech veh  atgm inf  arty totl
         ---- ---- ---- ---- ---- ---- ----| ---- ---- ---- ---- ---- ---- ----
Sit EDs  0.09 0.07 0.02 0.03 0.05 0.12     | 0.00 0.00 0.00 0.02 0.11 0.07
Short  X 1.00 1.00 1.00 1.00 1.00 1.00     | 1.00 1.00 1.00 1.00 1.00 1.00
  anti X 1.00 1.00 1.00 1.00 1.00 1.00     | 1.00 1.00 1.00 1.00 1.00 1.00
Tac EDs  0.09 0.07 0.02 0.03 0.05 0.12 0.39| 0.00 0.00 0.00 0.02 0.11 0.07 0.20

Loss  X  1.50 1.50 1.50 1.00 1.00 2.00     | 1.50 1.50 1.50 1.00 1.00 2.00
Short X  0.88 0.88 0.88 1.00 1.00 1.00     | 1.00 1.00 1.00 1.00 1.00 1.00
ED loss  .001 .001 .000 .000 .000 .001 .004| .000 .000 .000 .000 .002 .002 .004

2.10 force ratio, 0.01 def loss rate, 2.26 exchange rate, 0.01 att loss rate
 Med intensity stalemate in mountain terrain for 1.25 divs
 0.00 FLOT advance to 0.00 kms


Unit ARMD repairs at 0.30 rate, 20.00 max-move
Unit LID1 repairs at 0.30 rate, 20.00 max-move
Unit LID2 repairs at 0.30 rate, 20.00 max-move
```

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